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Distribution of Native and Exotic Earthworms in the Eastern United States: Implications for the Ecology of Vermivorous Snakes . . . . . Brian S. Gray 73

The Distribution of the Burmese Python, *Python bivittatus*, in China . . . . . David G. Barker and Tracy M. Barker 86

What You Missed at the April Meeting . . . . . John Archer 89

Herpetology 2010 92

Unofficial Minutes of the CHS Board Meeting, April 16, 2010 95

Advertisements 96

Cover: Midwestern wormsnake, *Carphophis amoenus helenae*, found 29 April 2010, eating an earthworm, species undetermined, on Pine Hills Road, Union County, Illinois. Photograph by Stephen L. Barten, DVM.

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Distribution of Native and Exotic Earthworms in the Eastern United States: Implications for the Ecology of Vermivorous Snakes

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Introduction

Earthworms are the primary prey documented for several North American snake species, including worm snakes (*Carphophis* spp.), earth snakes (*Virginia* spp.), swamp snake (*Seminatrix pygaea*), lined snake (*Tropidoclonion lineatum*), and short-headed garter snake (*Thamnophis brachystoma*) (Ernst and Ernst, 2003). However, more often than not, the earthworm species found to be preyed upon are not identified, and when they are, they represent European species introduced within the past 500 years (see Clark, 1970; Fitch, 1999; Pisani, 2009). The geographic distributions of the above-listed snake species occur mainly south of the boundary that represents the southernmost extension of the Wisconsinan glaciation. Furthermore, these snakes' distributions are sympatric with the majority of North America's native earthworms, and prior to the introduction of exotic earthworms, native earthworm species likely served as primary prey for these vermivorous (i.e., worm-eating) snakes. Vermivorous snake species are not restricted to unglaciated areas, however. In glaciated regions, Kirtland's snake (*Clonophis kirtlandii*), Butler's garter snake (*T. butleri*), and common garter snakes (*T. sirtalis*) include earthworms as a substantial component of their diets. The earthworm fauna in the glaciated north is almost exclusively exotic, suggesting that these snake species fed on something other than earthworms during recolonization of formerly glaciated regions (Reynolds, 1994a; Catling and Freedman, 1980). The ring-necked snake (*Diadophis punctatus*) and brown snake (*Storeria dekayi*) also have populations that feed primarily on earthworms. In this paper I discuss the relationships between vermivorous snakes and earthworms, and propose possible effects that exotic earthworms may have had, and may continue to have, on these snakes. I hope that the following discussion will encourage collaboration between herpetologists and oligochaetologists.

Glaciation and the distribution of worms and snakes

The last glacial event to affect North America was the Wisconsinan, which occurred during the Pleistocene Epoch and lasted approximately 100,000 years, beginning about 110,000 years before present (ybp) and ending around 10,000 ybp (Holman, 1995). During the Wisconsinan glacial event, massive ice sheets—the Cordilleran to the west and the Laurentide to the east—advanced and retreated, scouring the land beneath and creating the underlying topography seen in Canada and the northern United States. South of the ice sheets, a narrow 80–200 km belt of permafrost existed, where mean annual temperatures were likely less than −6°C (Dawson, 1992). After the final retreat of the ice sheets, ca. 15,000 ybp, bare ground consisting of sterile mud and unconsolidated sediments of gravel, sand and silt were left in their wake (Pielou, 1991; Holman, 1992, 1995). Such environments of bare rock and shallow soil are inhospitable for the development of biotic communities (Holman, 1992), and would have lacked adequate food (e.g., plant remains) for earthworms. According to the Post-Quaternary Introduction Theory of megadriles, earthworms occurred north of the southern limit of the Wisconsinan glaciation in North America prior to glaciation, but were extirpated during glaciation and have since been reintroduced by agents/vectors such as man (Reynolds, 1994a; Reynolds and Wetzel, 2004). Colonization of previously glaciated territory was probably slow, and it is likely that few native earthworms inhabited northern regions of North America at the time of European colonization about 500 years ago (Gates, 1967, cited in Hendrix and Bohlen, 2002). Furthermore, the ability of earthworms to migrate by their own means (0.5–1.0 km every 100 years; Marinissen and van den Bosch, 1992; Hale et al., 2006) is limited by their lack of limbs and eyes, their intolerance of ultraviolet radiation, and their dependence on moist habitats with sufficient dissolved oxygen for cutaneous respiration (James, 1984; Reynolds and Wetzel, 2004). During the Pleistocene, south of the ice sheets, summers may have been cooler and winters warmer, thus allowing northern and southern snake species to coexist (Harding and Holman, 1982; Holman, 1995).

As per Holman (1992), it is assumed that snakes (and earthworms) during the Pleistocene Epoch had the same ecological and physiological tolerances that they do today. It is also assumed that the presence of fossils of obligate vermivorous snake species, such as *Carphophis*, at a site implies that there were native earthworms there as well. Since earthworms do not fossilize well, their historic distributions prior to glaciation are not known (Proulx, 2003). Thus, using fossils to delineate the historic distributions of obligate vermivorous snakes may also serve as a baseline in the study of the historic distribution of native earthworms.

The worms and the snakes

Approximately 161 species (116 native, ca. 45 introduced) of earthworms have been described from North America north of Mexico (Reynolds and Wetzel, 2004). The native earthworms are found generally in the southeastern United States. Most of the earthworm species considered to be native to North America belong to the families Acanthodrilidae, Glossoscolecidae, Lutodrilidae, Komarekionidae and Sparganophilidae; however, several species in the genus *Bimastos* are in the family Lumbricidae. With the exception of the Pacific Northwest, where several native earthworms appear, Canada's earthworm fauna is primarily exotic (Fender, 1995; Hendrix and Bohlen, 2002). The exotic earthworms are primarily members of the families Lumbricidae and Megascolecidae; several species in the families Octochaetidae and Ocnerodrilidae have also been introduced (Reynolds and Wetzel, 2004). The introduced earthworm species are

primarily of European origin, although members of the genera *Amynthas* and *Metaphire* are native to the Orient, mainly China and Japan (Reynolds, 1978). The introduction of exotic earthworms into North America is a relatively recent phenomenon, and most species were likely brought over in soil and plant roots by European settlers. Presently, discarded earthworms used as fishing bait and transport of earthworm cocoons via mud in tire treads are assumed to be important anthropogenic routes of dispersal of exotic earthworms into northern hardwood forests that previously lacked native earthworms (Cameron et al., 2007; Keller et al., 2007; Hale, 2008). It is also possible that earthworm cocoons (native and exotic) may be transported in mud on the feet of wading birds. Pisani (pers. com.) suggested that earthworm cocoons may also be dispersed in moist soil on the fur or hooves of large ungulates (e.g., deer, elk or bison). Today, some sites still lack earthworms; others may harbor earthworm species that are entirely native, a mixture of native and exotic species, or completely exotic (Hendrix and Bohlen, 2002).

Different species of earthworms utilize different microhabitats; for instance, epigeic species are litter- and surface-dwelling earthworms exemplified by some native *Diplocardia* spp. and the exotic *Lumbricus rubellus*. The endogeic earthworms are soil-dwelling; *Aporrectodea* spp. and *Octolasion tyrtaeum* are exotic examples. The anecic species are deep burrowers, such as the exotic nightcrawler, *Lumbricus terrestris*. Knowing the type of earthworm that a snake feeds upon may allow speculation about the snake's foraging habits—for instance, an observation that only endogeic species are utilized implies that the snake may burrow when feeding. Addison (2008) cautioned that the actual behavior of earthworms may not always conform to such classification. For example, endogeic *Aporrectodea turgida* feed below the soil surface, but cast on the soil surface. Furthermore, heavy rains may bring earthworms of all categories to the surface; it is therefore important to take previous precipitation into account when interpreting such data. Due to differences in habitat selection and/or behavior, not all species of earthworms may be available as prey to predators including snakes (Reynolds, 1977a). For instance, *Sparganophilus* spp. and *Lutodrilus multivasiculatus* are limicolous (mud-dwelling) species; most *Bimastos* and *Eisenoides* species are confined to forests; and some species of *Diplocardia* feed on surface litter, while others feed in the subsoil, consuming humus (Reynolds, 1980; James, 1995; Kalisz and Wood, 1995). Earthworms in the genus *Amynthas* are very active (Reynolds, 1978), and their erratic writhing and jumping may prevent small snakes such as *Carphophis amoenus* from successfully subduing them. I have personally observed this in captive *C. amoenus* and *T. brachystoma*. The snakes attempted to grasp the worms, but released them after only a few seconds; apparently because of the worms' erratic and animated behavior.

As with most dichotomies, the classification of obligate and facultative vermivorous snakes presented here has its weaknesses. In particular, juveniles of almost all the species discussed are obligate vermivores. Also, some populations of facultative vermivorous snakes may, in fact, be obligate vermivores (e.g., *Diadophis punctatus* in eastern Kansas [Pisani, 2009]). Furthermore, the distribution of native earthworms in some states is incomplete; therefore, the amount of overlap with the ranges of some vermivorous snakes is not fully known (see the discussion of *Tropidoclonion lineatum* below).

The following snake species are obligate vermivores, and each species shares a combination of at least four of the following characteristics: 1) earthworms are the only prey item documented from most populations; 2) their distributions are primarily restricted to unglaciated regions, with the majority (at least 75%) of their range sympatric with that of at least one native earthworm species; 3) they are usually found in damp or moist situations; 4) they are small species, usually less than 50 cm total length (TL); and 5) they have a limited gape that restricts them to feeding on elongate prey.

The eastern worm snake, *Carphophis amoenus*, is a small (to 35 cm TL [Ernst and Ernst, 2003]) snake with a tan to brownish dorsum and pinkish translucent ventral surface. It has a narrow, dorsoventrally flattened head; a cylindrical body; smooth scales; tiny eyes; and a short spine-tipped tail—all morphological features indicative of a burrowing life style (Gibbs et al., 2007).

The geographic distribution of *C. amoenus* is primarily south of the southernmost boundary of the Wisconsinan Glaciation. Ernst and Ernst (2003) give the distribution as extending from southern New England, southeastern New York, eastern Pennsylvania, southern Ohio, southern Indiana and southern Illinois, south to South Carolina, northern Georgia, Alabama, southeastern Louisiana, and eastern Arkansas. The eastern worm snake is

Table 1. The degree of overlap between the geographic distributions of vermivorous snakes and native earthworms. Obligate vermivores are listed in bold italics; facultative vermivores are listed in regular italics. Y indicates that significant (90–100%) overlap does occur. P indicates partial overlap occurs, with 25, 50, and 75 representing the approximate percentage of partial overlap. N indicates that there is very little (less than 10%) to no overlap in the ranges.

	Native earthworm genera				
Snake species	*Bimastos*	*Diplocardia*	*Eisenoides*	*Komarekiona*	*Sparganophilus*
Carphophis amoenus	Y	Y	Y	Y	Y
C. vermis	Y	Y	P50	N	Y
Clonophis kirtlandii	Y	Y	P25	P25	Y
Diadophis punctatus	Y	Y	Y	Y	Y
Seminatrix pygaea	Y	Y	Y	N	Y
Storeria dekayi	Y	Y	Y	P50	Y
Thamnophis brachystoma	Y	Y	P25	N	Y
T. butleri	Y	P75	N	N	Y
T. sirtalis	Y	Y	Y	Y	Y
Tropidoclonion lineatum	P50	P50	N	N	P25
Virginia pulchra	Y	Y	P50	P50	Y
V. striatula	Y	P75	P75	N	P75
V. valeriae	Y	Y	P75	P50	P75

most often found in ecotonal areas of open to thick woodlands, and the borders of wetlands. Such sites also need to have an abundance of cover in the form of rocks, logs, and leaf litter (Ernst and Ernst, 2003). Throughout this species' range, it is excluded from areas with particularly compact soils (Gibbs et al., 2007). In Connecticut, Klemens (1993) noted that "worm snakes may be excluded from higher elevations by poorly drained and rocky soils, which are not suitable for burrowing and by late spring and early autumn frosts." These situations are also unfavorable to earthworms. In Mississippi, Cook (1954) found worm snakes under rotten logs and leaves on wooded hillsides; the endemic earthworms in the genus *Bimastos* may be found in similar habitats.

Several references note that *C. amoenus* is primarily an earthworm predator, but do not specify whether or not the earthworm species consumed were native (e.g., Mount, 1975; Bush, 1959; Mitchell, 1994; Hulse et al., 2001). The range of *C. amoenus* is within the range(s), in part or whole, of native earthworms in the following genera: *Bimastos*, *Diplocardia, Eisenoides* and *Sparganophilus* (Table 1) (see James [1995] for maps). *Carphophis amoenus* was reported by Means (cited in Reynolds, 1980) in *Sparganophilus eiseni* habitat. All genera of exotic earthworms discussed in this paper have ranges that overlap with the range of *C. amoenus* (Table 2). In captivity, an eastern worm snake readily consumed the exotic earthworms *Aporrectodea tuberculata, Lumbricus rubellus*, and pieces of *L. terrestris*, but refused *Amynthas agrestis* (pers. obs.).

North of the glacial boundary in southeastern New York, Connecticut, Rhode Island and southern Massachusetts, workers may wish to focus on determining if native earthworms are found at sites with *C. amoenus*. Documented occurrences of endemic earthworms in New England are rare—for instance, *Bimastos parvus* in Massachusetts; *Eisenoides lonnbergi* in Connecticut, Massachusetts and Rhode Island (Reynolds, 2002; Reynolds and Wetzel, 2008); and *Sparganophilus eiseni* in Connecticut and Massachusetts (Reynolds, 1980). Also, the ranges of *Sparganophilus*, *Bimastos*, *Eisenoides* and *Diplocardia* extend into southern Georgia and Florida (Reynolds, 1994b; James, 1995), where extant populations of *C. amoenus* have not been documented and are assumed to be absent. Therefore, effort should be made to survey for *C. amoenus* at sites with native earthworms in these two southern states. During the Pleistocene Epoch *Carphophis amoenus* was present well south of its current range, in Alachua, Citrus, Marion and Sumpter counties in Florida (Holman, 2000).

The western worm snake, *C. vermis*, like the eastern worm snake, is a small (to 39.1 cm TL [Ernst and Ernst 2003]) snake species with a dark gray to gray-violet dorsum, and pinkish ventral surface. It is also similar to *C. amoenus* in having morphological features that facilitate burrowing (e.g., smooth scales; small, flattened head; etc.).

Carphophis vermis is found from southern Iowa and southeastern Nebraska south to northwestern Louisiana and northeastern Texas. Isolated populations occur in west-central Illinois,

Table 2. The degree of overlap between the geographic distributions of vermivorous snakes and exotic earthworms. Obligate vermivores are listed in bold italics; facultative vermivores are listed in regular italics. Y indicates that significant (90–100%) overlap does occur. P indicates partial overlap occurs, with 25, 50, and 75 representing the approximate percentage of partial overlap. N indicates that there is very little (less than 10%) to no overlap in the ranges.

	Exotic earthworm genera						
Snake species	*Allolobophora*	*Aporrectodea*	*Dendrobaena*	*Dendrodrilus*	*Lumbricus*	*Octolasion*	*Amynthas*
Carphophis amoenus	P75	Y	Y	Y	P75	Y	Y
C. vermis	N	Y	P50	P50	P50	P50	Y
Clonophis kirtlandii	Y	Y	Y	Y	Y	Y	P25
Diadophis punctatus	Y	Y	Y	Y	Y	Y	P50
Seminatrix pygaea	N	P75	N	N	N	P50	P50
Storeria dekayi	Y	Y	Y	Y	Y	Y	Y
Thamnophis brachystoma	Y	Y	Y	Y	Y	Y	P25
T. butleri	Y	Y	Y	Y	Y	Y	N
T. sirtalis	Y	Y	Y	Y	Y	Y	Y
Tropidoclonion lineatum	N	Y	N	N	N	N	P25
Virginia pulchra	Y	Y	Y	Y	Y	Y	N
V. striatula	N	Y	P50	P50	P25	P50	P75
V. valeriae	P25	Y	P50	P50	P50	P50	P75

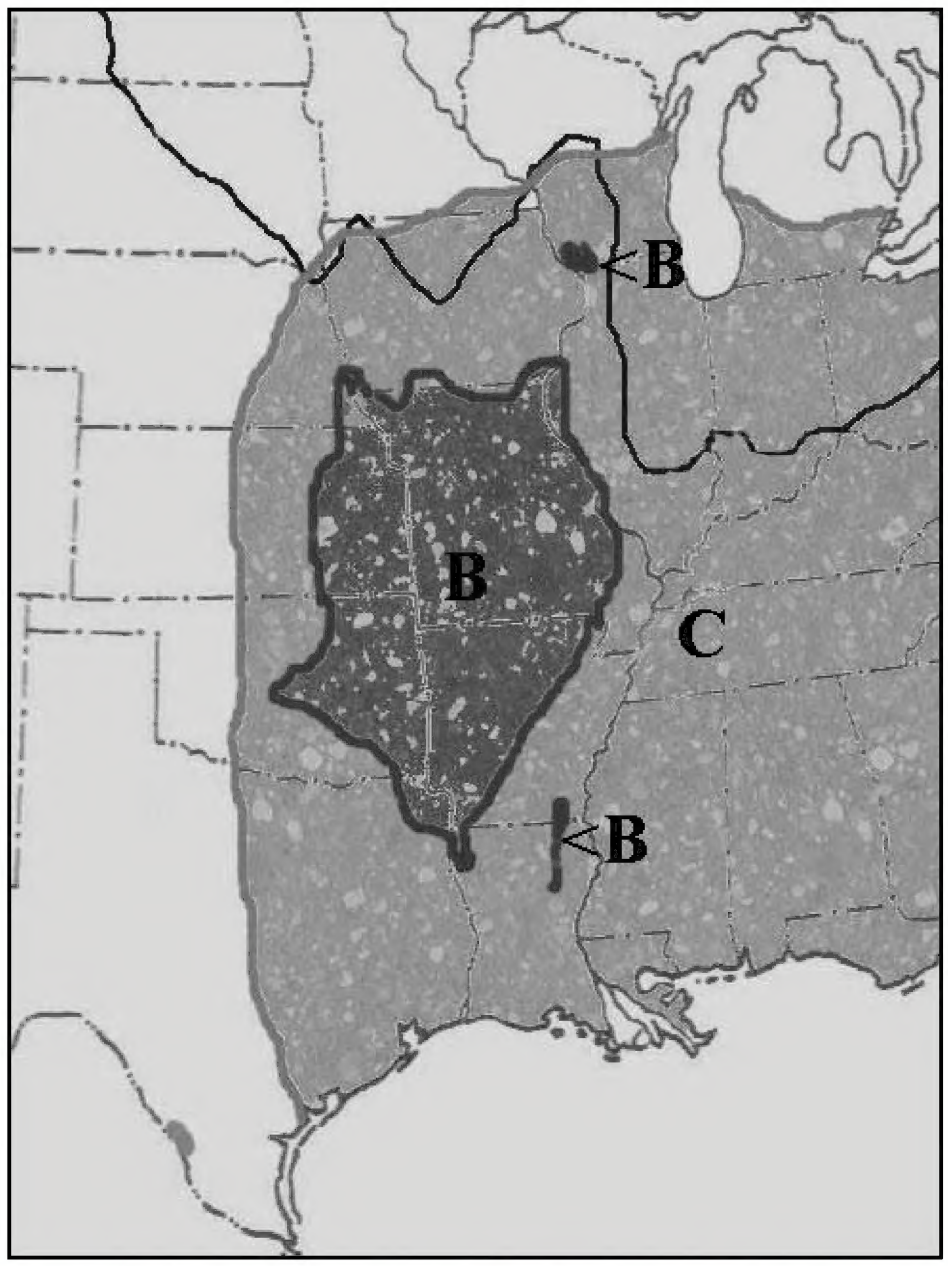

Figure 1. The approximate range of *Carphophis vermis* (adapted from Ernst and Ernst, 2003) and the combined ranges of native earthworms. Dark shaded areas labeled "B" represent areas of overlap between *C. vermis* and native earthworms. Areas of lighter shading labeled "C" represent the combined ranges of native earthworms. The black line represents the southernmost extension of the Wisconsinan Glaciation. The combined ranges of approximately 100 Nearctic earthworm species, some tentative and some with very limited distribution, are adapted from Hendrix and Bohlen (2002).

southwestern Wisconsin, southeastern Arkansas and northeastern Louisiana (Figure 1). The western worm snake has been reported from moist, rocky woodlands, and in prairies may be found along wooded streams (Ernst and Ernst, 2003). Pisani (2009) found *C. vermis*—and *Virginia valeriae*—beneath shelters in Tall Grass Prairie habitat with a dense thatch layer. *Carphophis vermis* and *C. amoenus* have similar soil moisture preferences, 10–83% and 16–42%, respectively (Clark, 1970; Elick and Sealander, 1972; Orr, 2006). Such soil moisture levels not only aid in preventing desiccation in *C. vermis*, but are also necessary for optimum cutaneous respiration of the earthworms this snake consumes. Moist substrates are also selected by snakes seeking suitable egg-laying sites. Furthermore, earthworms of temperate climates prefer similar soil temperatures (10–20°C) and soil pH (5.0–7.4) as *Carphophis* spp. (Curry, 2004; Orr, 2006).

The native earthworm genera *Bimastos, Diplocardia, Eiseinoides* and *Sparganophilus* all have ranges that overlap with the range of *C. vermis* (Table 1), as do most exotic genera considered herein (Table 2). Only exotic earthworm species (*Allolobophora tuberculata, A. turgida*, *A. trapezoides* and *Lumbricus* spp.) have been documented as prey of *C. vermis* (Clark, 1970; Ernst and Ernst, 2003). These earthworms are endogeic (soil-dwelling) species, suggesting that *C. vermis* burrows in search of prey. In addition to the above exotic species, *Eisenia* sp. and *Octlasion* sp. have been listed as possible prey (Clark, 1970). However, within the range of *C. vermis*, *Eisenia hortensis* is uncommon (only found in Arkansas [Reynolds and Wetzel, 2008]) and *E. foetida* has a pungent coelomic fluid reportedly toxic to snakes (Rossman et al., 1996); it is therefore not likely to be consumed. *Octolasion*, on the other hand, is only found in the eastern part of the range of *C. vermis*. Incidentally, *Allolobophora caliginosa* was found to be a group of 3–4 species in the larger *trapezoides* complex of up to seven earthworm species in the genus *Aporrectodea* (Reynolds, 1995; Reynolds and Wetzel, 2004). Therefore, unless preserved specimens are available, it may not be possible to positively identify to which species older records listing *A. caliginosa* as a food item refer.

Since exotic species of earthworms primarily have been reported in the diet of *C. vermis*, it can be assumed that a shift from native to exotic species of earthworms in the diet may have taken place in some populations (Clark, 1970). Efforts should be made to document native earthworm species in the diet of the western worm snake. If sites are found with both native and exotic species of earthworms, studies could be done to determine if one is favored or more accessible than the other, and verify whether a shift from natives to exotics occurs. Clovis Period (ca. 11,100 ybp) fossils of *C. vermis* have been found in Lubbock County, Texas, well west of the limits of the current range of this species (Holman, 2000). It is reasonable to assume that native earthworms occurred at the site as well.

The mountain earth snake, *Virginia pulchra*, is a tan to reddish-brown, small (to 38.1 cm TL) snake. Compared to *Carphophis*, species in the genus *Virginia* have stouter bodies, more cone-shaped heads (Ernst and Ernst, 2003), and stronger tendencies toward surface foraging (Pisani, 2009).

Virginia pulchra is found on the Allegheny Plateau and Allegheny Mountains of western Pennsylvania, the western panhandle of Maryland, eastern West Virginia, and a small portion of northern Virginia. Grassy hillsides and ecotonal areas at the edge of deciduous forests and fields are favored habitats.

Although earthworms are listed in the diet (e.g., Green and Pauley, 1987; Hulse et al., 2001), they are not identified to genus or species. Therefore, the documentation and identification of any earthworm species in the diet of *V. pulchra* would be of interest. All genera of native earthworms are known from within the range of *V. pulchra* (Table 1); *Amynthas* is the only exotic earthworm genus that is not sympatric with the mountain earth snake (Table 2). In captivity, this species fed upon exotic *Aporrectodea tuberculata, Lumbricus rubellus* and *L. terrestris* (pers. obs.).

The rough earth snake, *Virginia striatula*, is a small (to 34.8 cm TL [Ernst and Ernst, 2003]), nondescript, gray-brown to reddish-brown snake. Unlike *Carphophis*, rough earth snakes have keeled dorsal scales, slightly stouter bodies, and cone-shaped heads (Ernst and Ernst, 2003).

Ernst and Ernst (2003) delineate the distribution of *V. striatula* as ranging from southeastern Virginia south to northern

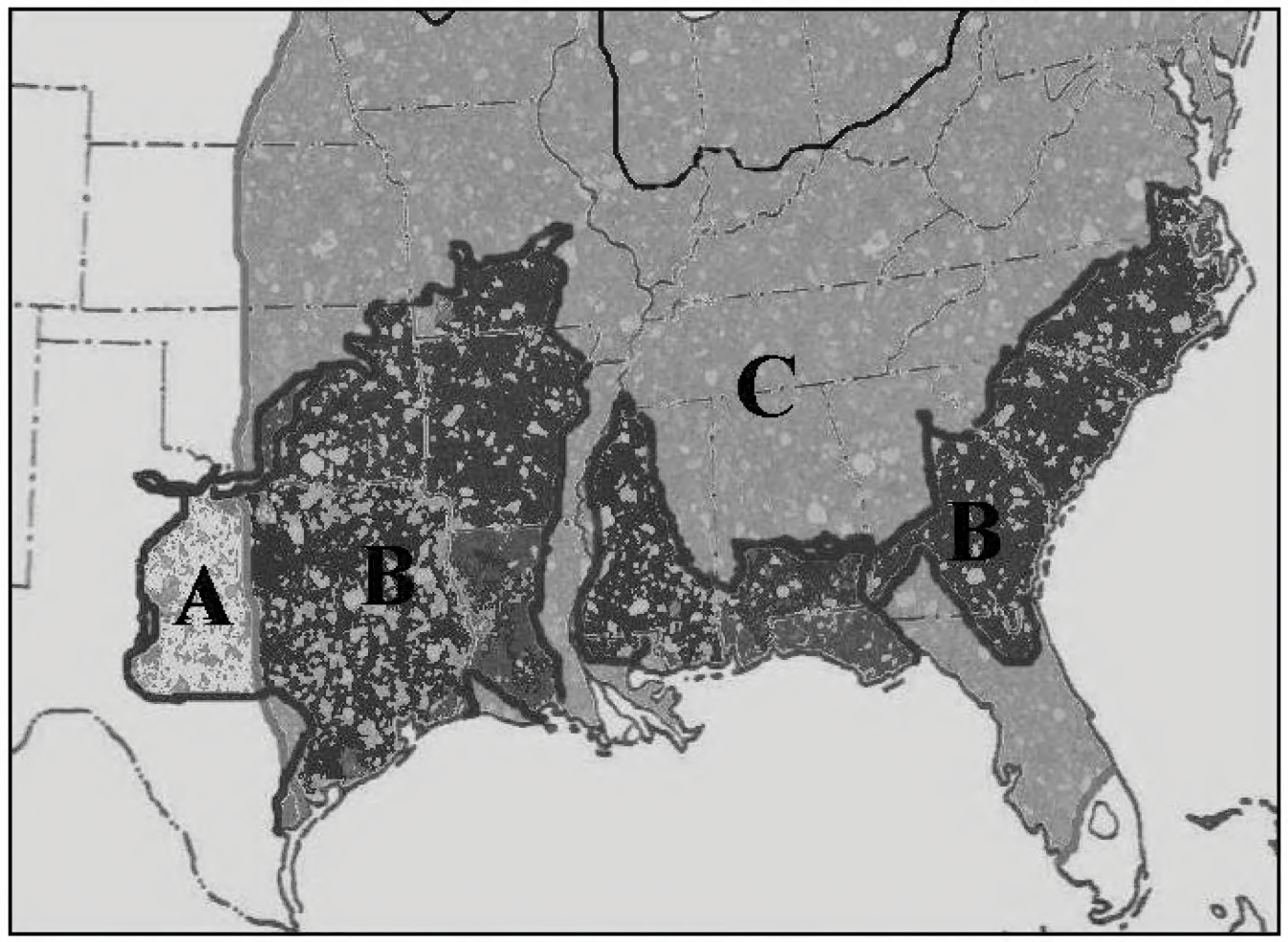

Figure 2. The approximate range of *Virginia striatula* (adapted from Ernst and Ernst, 2003) and the approximate combined ranges of native earthworms. Lightly shaded areas labeled "A" represent western portion of *V. striatula*'s range that does not overlap that of native earthworms. Darker shaded areas labeled "B" represent the portion of *V. striatula*'s range that overlaps that of native earthworms. Moderately shaded area labeled "C" is the remainder of the combined ranges of native earthworms. The black line represents the southernmost extension of the Wisconsinan Glaciation. The combined ranges of approximately 100 Nearctic earthworm species, some tentative and some with very limited distribution, are adapted from Hendrix and Bohlen (2002).

Florida, west across Georgia, Alabama and most of Mississippi to southeastern Louisiana, and from southern Missouri and extreme southeastern Kansas southward through western Arkansas, western Louisiana, eastern Oklahoma, and eastern Texas. *Virginia striatula* prefers wooded areas and ecotones, and can be found beneath rocks, logs, and under bark (Allen, 1932; Cook, 1954; Ernst and Ernst, 2003).

The geographic distribution of *V. striatula* and that of native earthworms (*Bimastos* spp., *Diplocardia* spp., *Eisenoides* spp., and *Sparganophilus* spp.) overlap considerably (Table 1) (Figure 2), yet no reports specifically identify native earthworms in the diet of the rough earth snake (Clark and Fleet, 1976; Linzey and Clifford, 1981; Palmer and Braswell, 1995; Trauth et al., 2004). Populations of *V. striatula* in central Texas are outside the documented range of native earthworms, and it is likely that *Aporrectodea* is fed upon there. Alternatively, it is possible that native earthworm populations exist, but have not been discovered yet. Of the exotic earthworm genera, only the distribution of *Allolobophora* does not overlap with that of the rough earth snake (Table 2). Researchers should make an effort to determine which native earthworms are consumed by *V. striatula*.

The eastern earth snake, *Virginia valeriae*, is a small (to 39.3 cm TL [Smith and Brodie, 1982]) nondescript, tan to light brown snake. Unlike *V. pulchra* and *V. striatula*, the eastern earth snake has smooth scales.

Virginia valeriae is distributed in unglaciated territory from New Jersey, Delaware, Pennsylvania and southern Ohio west to southwestern Illinois and southern Iowa, and south to northern Florida and central Texas (Ernst and Ernst, 2003). Cook (1954) noted that *V. valeriae* burrowed under rotten leaves and bark, and in decayed wood in forested areas—habitat similar to that favored by some native earthworms in the genus *Bimastos*. In Kansas, Pisani (2009) observed that *V. valeriae* utilized dense thatch in Tall Grass Prairie.

Earthworms are listed as the main food item (Conant, 1938; Hulse et al., 2001; Pisani, 2009), but have not been identified to specific taxa. All genera of native earthworms (Table 1) and all genera of exotic earthworms (Table 2) have ranges sympatric with *V. valeriae*. Efforts to identify the earthworm species preyed upon would be of interest to both herpetologists and oligochaetologists.

The short-headed garter snake, *Thamnophis brachystoma*, is the smallest of the garter snake species (up to 57.8 cm TL [Lethaby, 2004]). It has a narrow head and the typical garter snake pattern of lateral and vertebral stripes on the body.

Thamnophis brachystoma is endemic to the Allegheny High Plateau of northwestern Pennsylvania and adjacent southwestern New York; isolated populations also exist in eastern Ohio (Novotny, 1990; Novotny, pers. com.) and Horseheads, New York (Wright and Wright, 1957). It prefers open areas such as old fields and meadows, and avoids deep woodlands (Rossman et al., 1996).

Earthworms are the only prey item presently documented from wild *T. brachystoma* (Asplund, 1963; Wozniak and Bothner, 1966); however, it is unknown whether these represent native or exotic species. In captivity *T. brachystoma* fed on *Aporrectodea* sp., *Lumbricus rubellus* and *Lumbricus terrestris* (pers. obs.). In glaciated territory *T. brachystoma* most certainly

preys upon ubiquitous exotic earthworms. Within the range of *T. brachystoma* the following native earthworm species have been documented (Reynolds, 2007, 2008a and b): *Bimastos tumidus*, *B. parvus*, *Diplocardia* spp., *Eisenoides lonnbergi* and *Sparganophilus eiseni* (Table 1). However, because *S. eiseni* is a mud-dwelling species, it is not likely to be available as a food item in this snake's diet. Also, *E. lonnbergi* and *Bimastos* spp. prefer forested areas with high organic matter present (James, 1995; Reynolds, 2008a), and these differences in habitat preferences would cause these earthworms to rarely be encountered by *T. brachystoma*. Therefore, *Diplocardia* spp. constitute the most likely group of native earthworms to be fed on by *T. brachystoma*. All genera of exotic earthworms considered herein have ranges that overlap with *T. brachystoma* (Table 2).

Weatherhead and Madsen (2009) noted that some snake species have benefited from invasive species. One example given was the Lake Erie water snake (*Nerodia sipedon insularum*) which feeds on the now abundant invasive round goby (*Neogobius melanostomus*). Likewise, the vermivorous snakes discussed in this paper may have benefited from the introduction of exotic earthworms. In glaciated regions in Erie County, Pennsylvania, and Horseheads, New York, *T. brachystoma* has successfully been established in areas for the most part devoid of native earthworms (Engelder, 1988; Gray, 2005); the presence of exotic earthworm species probably facilitated these establishments. Alternatively, there is anecdotal evidence that *T. brachystoma* may include a greater diversity of prey items (e.g., leeches, fish and amphibians) in its diet than previously thought, which may have aided in colonization into glaciated areas prior to the introduction of exotic earthworms (Gray, 2008). Fossils from Blair County, Pennsylvania, and Pendleton County, West Virginia, indicate that during the Pleistocene, *T. brachystoma* had a range that extended much further south than it does presently (Holman, 2000). Very little sampling has been done for earthworms within the core range of *T. brachystoma*—for instance, in Pennsylvania there are no earthworm records (native or exotic) for Clarion, Forest, Jefferson, McKean or Warren Counties, and only single collections from Allegheny, Clearfield, Elk, and Venango Counties (Reynolds, 2008a). In New York, Allegany, Cattaraugus, Chautauqua, and Chemung Counties have 1–2 collections each (Reynolds, 2008b). Therefore, records of earthworms found in association with, or consumed as prey by, *T. brachystoma* in these regions could add significantly to our knowledge of the distribution of earthworms, and the feeding habits of the short-headed garter snake.

The following snake species are facultative vermivores, and most adults share the following characteristics: 1) earthworms may form the bulk of their diet, yet other food items are reported among populations; 2) their distributions extend well into glaciated regions where native earthworms would have been absent post-glaciation; 3) they may be found in damp or moist situations, but also drier settings; 4) they usually attain a TL greater than 50 cm; and 5) their gape can accommodate larger prey that may not be elongate. *Diadophis punctatus* is an exception to this last characteristic, as it is very gape limited.

Holman (1992) proposed a model for herpetological reoccupation of formerly glaciated Michigan. He used a variety of data from geological, paleobotanical and paleovertebrate assemblages, as well as from ecological tolerances of modern herpetofauna. In Holman's model there are primary invaders, the first species of amphibians and reptiles to begin colonizing. Their ecological tolerances included adaptation to coniferous forests; *Diadophis punctatus* and *Thamnophis sirtalis* are examples. Secondary invaders were next to colonize, and have ecological tolerances including an adaptation to mixed coniferous–broadleaf areas; *Thamnophis butleri* is an example. Finally, the third and last group of colonizers is named tertiary invaders, and is adapted to exist in broadleaf forest areas; *Clonophis kirtlandii* exemplifies this group. Because earthworms were absent after the retreat of the glaciers, all these snakes must have fed on something other than earthworms during reoccupation; for example, primary colonizers may have fed on other primary colonizers (e.g., *Diadophis punctatus* on *Plethodon cinereus*, or *T. sirtalis* on *Lithobates* (= *Rana*) spp.); secondary colonizers may have fed on primary and other secondary invaders, etc. Whatever they fed upon during that time, a shift to exotic earthworms has occurred within the past 500 years.

Kirtland's snake, *Clonophis kirtlandii* (to 62.2 cm TL [Smith and Brodie, 1982]), has a brownish dorsum with dark, almost black, alternating blotches; the ventral surface is orangish to red. *Clonophis kirtlandii* is a snake of the Prairie Peninsula and is known from west-central Pennsylvania westward through southern Ohio, Indiana, southern Michigan, north-central Kentucky and central Illinois (Ernst and Ernst, 2003).

Throughout the range of *C. kirtlandii*, earthworms are the most commonly found prey in the diet (Conant, 1943; Smith, 1961; Minton, 1972; Hulse et al., 2001; Holman and Harding, 2006), and since this snake is distributed mainly in glaciated regions it is assumed the earthworms represent exotic species; identification of regurgitated stomach contents of live snakes or dissection of preserved specimens may verify this. In the southern part of the range of *C. kirtlandii*, native earthworms in the genera *Bimastos, Diplocardia, Eisenoides, Komarekiona,* and *Sparganophilus* occur, and efforts to identify earthworms preyed upon or in association with *C. kirtlandii* in this region are needed. It cannot be known what *C. kirtlandii* fed on south of the glacier during the Pleistocene; however, assuming prey preferences then were similar to those today, Kirtland's snake may have fed on native earthworms, as well as slugs and leeches.

The ring-necked snake, *Diadophis punctatus*, is usually some shade of gray to bluish black dorsally with a cream, yellowish, or reddish collar on the nape. In the eastern part of its range it is yellowish ventrally; in the west it is more orange to red. *Diadophis punctatus* attains a maximum TL of 85.7 cm (Ernst and Ernst, 2003); however, the subspecies *punctatus* and *edwardsii* are usually less than 50.0 cm TL.

The ring-necked snake is widely distributed throughout much of the United States and Canada, from New Brunswick and Nova Scotia west to Lake Superior, southern Quebec and Ontario, south to the Florida Keys and west to Texas, New Mexico, Arizona and southern California. Isolated populations occur in the Great Basin from southeastern Washington to northwestern Arizona, and in southeastern California (Ernst and Ernst, 2003).

Across the range of the ring-necked snake, there is a great deal of variety in the diet (see Ernst and Ernst [2003] for a summary), with populations predominantly feeding on one, or a combination of, the following: earthworms, salamanders, and other snakes. In parts of North Carolina, ground skinks (*Scincella lateralis*) are occasionally eaten (Jeff Beane, pers. com.). There are some interesting observations to be made regarding the diet of *D. punctatus*; for instance, in North Carolina, earthworms are more frequently observed as prey in the Coastal Plain, whereas in the mountains, plethodontid salamanders dominate (Palmer and Braswell, 1995). One would expect earthworms to be more abundant than salamanders in the Coastal Plain, and the converse to be true in the mountains. As noted above in the discussion of the worm snake, earthworms are usually absent from mountainous areas, due in part to shallow soil or bare rock, wind-induced desiccation, elevated ultraviolet radiation, reduced oxygen, and limited suitable food, all of which act as barriers to earthworm migration (Reynolds and Wetzel, 2004). Hulse et al. (2001) mention that in the eastern United States where salamanders are common, they are the major component of the diet of *D. punctatus*; where salamanders are rare, earthworms are the major prey. It would also be expected that north of the glacial boundary, where native earthworms are absent, *D. punctatus* would feed predominantly on salamanders, and in Michigan, glaciated regions of Pennsylvania, New England, and Ontario this seems to be the case (Blanchard, 1942; Logier, 1958; Serrao, 2000; Krulikowski, 2004; Gray and Lethaby, 2008). In northeastern Kansas, exotic earthworms (*Allolobophora caliginosa*) are the predominant prey (Fitch, 1975; Pisani, 2009). The range of *D. punctatus* overlaps that of all native earthworm genera (Table 1) and all exotic genera (Table 2). As noted above, *Sparganophilus* is a mud-dwelling species and therefore unlikely to be available as prey for the ring-necked snake. In areas south of the glacial boundary, effort should be made to identify the species of earthworms being preyed upon, whether native or exotic.

The swamp snake, *Seminatrix pygaea*, like other vermivorous snake species is relatively small (to 55.5 cm TL [Ernst and Ernst, 2003]); however, unlike them it is a more aquatic species, preferring plant-choked wetlands, and much of its feeding is reportedly in water. It is distributed in the southeastern United States along the Atlantic Coastal Plain from North Carolina to Florida and adjacent southern Alabama.

Seminatrix pygaea has a more diverse diet, consisting of oligochaete worms, leeches, fish, and amphibians (Dowling, 1950; Tennant and Bartlett, 2000; Ernst and Ernst, 2003). *Seminatrix pygaea* is reported from the type locality of *Sparganophilus helenae* (Reynolds, 1980), and possibly feeds on this native earthworm species. *Komarekiona* is the only native earthworm genus not sympatric with *S. pygaea* (Table 1); the exotic genera *Amynthas, Aporrectodea* and *Octolasion* overlap this snake's range (Table 2).

The brown snake, *Storeria dekayi*, is a small species (to 52.7 cm TL [Smith and Brodie, 1982]), and is widely distributed in the eastern United States and southern Ontario, Canada. It is found in glaciated and unglaciated regions. Because *S. dekayi* has keeled scales and a blunt head it probably does not burrow, and likely feeds on the surface.

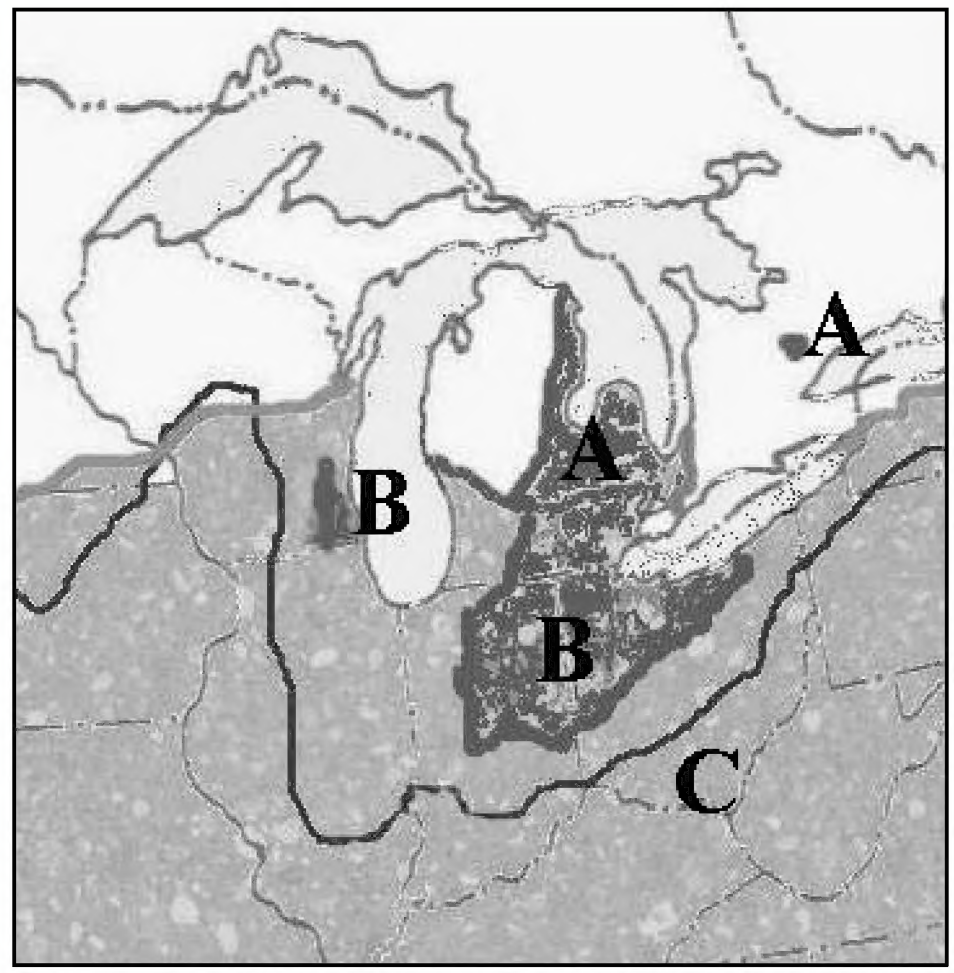

Figure 3. The approximate range of *Thamnophis butleri* (adapted from Ernst and Ernst, 2003) and the approximate combined ranges of native earthworms. The dark shaded areas labeled "A" represent the portion of the range of *T. butleri* that does not overlap the combined ranges of native earthworms. The dark areas labeled "B" represent the portions of the range of *T. butleri* that overlap the combined ranges of native earthworms. The area labeled "C" represents the remainder of the combined ranges of native earthworms. The black line represents the southernmost extension of the Wisconsinan Glaciation. The combined ranges of approximately 100 Nearctic earthworm species, some tentative and some with very limited distribution, are adapted from Hendrix and Bohlen (2002).

In northeastern Kansas, Pisani (2009) observed that *S. dekayi* feeds predominantly on earthworms. In other areas, however, brown snakes feed on slugs and earthworms (Logier, 1958; Mitchell, 1994; Palmer and Braswell, 1995; Hulse et al., 2001; Trauth et al., 2004). In northwestern Pennsylvania, slugs are preferentially taken by captives, although some individuals have eaten *Lumbricus terrestris* (pers. obs.). Incidentally, like earthworms, slugs are rarely identified to species and it is not known whether they represent native or exotic taxa. The range of *S. dekayi* overlaps significantly with all native earthworm genera (Table 1), as well as all exotic genera (Table 2).

Butler's garter snake, *Thamnophis butleri*, is similar in appearance to, but larger than (to 73.7 cm TL [Ernst and Ernst, 2003]) its closest relative, the short-headed garter snake. Unlike *T. brachystoma*, however, *T. butleri* is distributed mainly in formerly glaciated regions of Ohio, Indiana, Michigan, Wisconsin and southern Ontario. Butler's garter snake prefers wet, open areas such as prairies and pastures, but may also be found in urban settings (Ernst and Ernst, 2003).

Thamnophis butleri feeds on earthworms, leeches, and occasionally other prey such as small frogs (Rossman et al., 1996). The range of Butler's garter snake overlaps that of the native earthworm genera *Bimastos*, *Diplocardia*, and *Sparganophilus* (Table 1) (Figure 3); all genera of exotic earthworms except *Amynthas* also have overlapping ranges with *T. butleri*

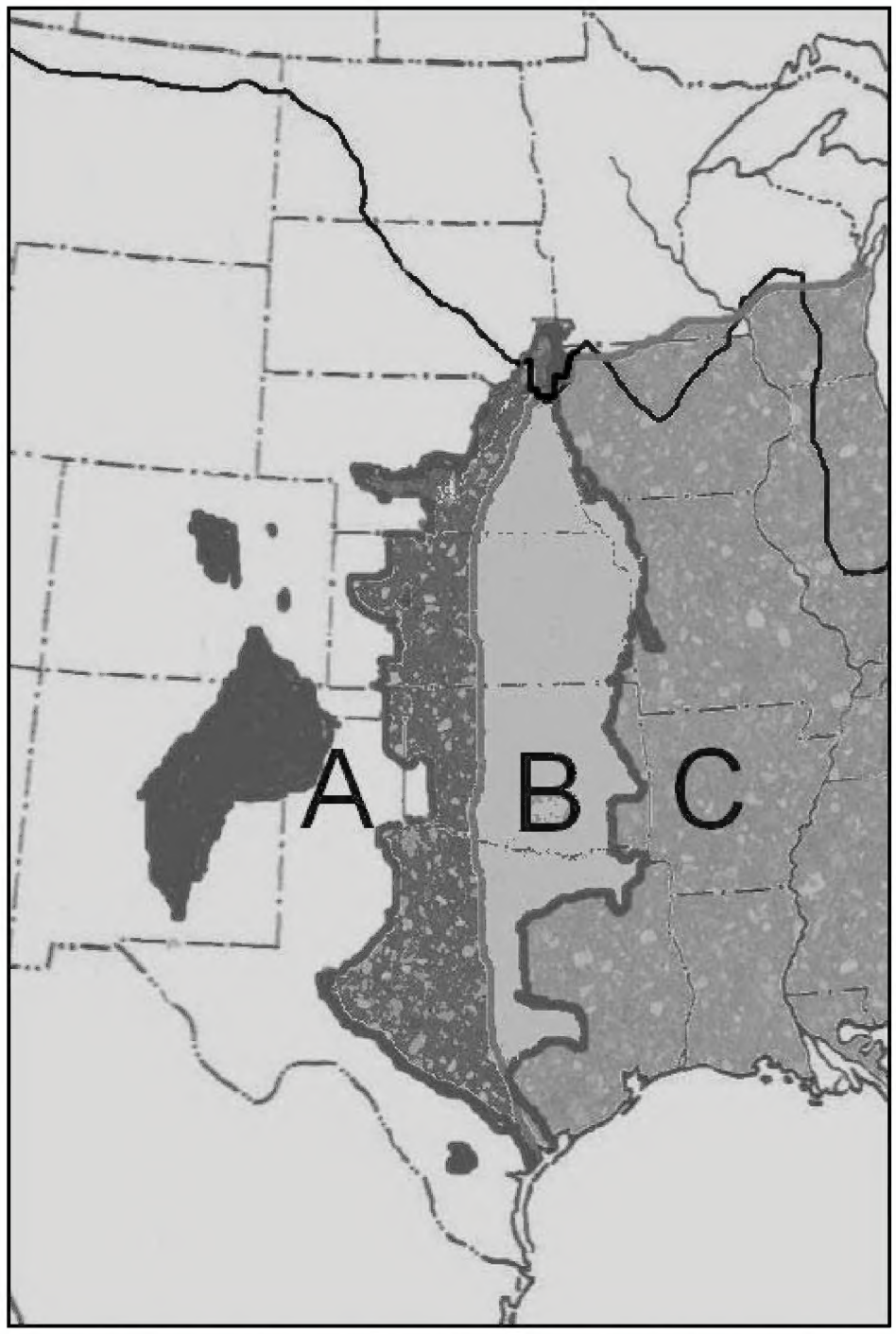

Figure 4. The approximate range of *Tropidoclonion lineatum* (adapted from Ernst and Ernst, 2003) and the approximate combined ranges of native earthworms. Dark shaded areas labeled "A" represent the western portion of *T. lineatum* range that does not overlap that of native earthworms. Lightly shaded area labeled "B" represents the eastern portion of *T. lineatum* range that overlaps that of native earthworms. Moderately shaded area labeled "C" is remainder of combined native earthworm ranges. The black line represents the southernmost extension of the Wisconsinan Glaciation. The combined ranges of approximately 100 Nearctic earthworm species, some tentative and some with very limited distribution, are adapted from Hendrix and Bohlen (2002).

(Table 2). Earthworms in the genus *Bimastos* are usually found in forested areas under logs, bark or leaf packs (James, 1995; Reynolds, 2007), and therefore are less likely to be utilized as food by *T. butleri*. Only exotic species of earthworms (*Allolobophora chlorotica*, *Aporrectodea* sp., *Lumbricus terrestris*, and *Lumbricus* sp.) have been reported in the diet of *T. butleri* (Catling and Freedman, 1980).

Holman (1992) considered *T. butleri* a secondary invader of formerly glaciated Michigan. As earthworms were absent during the recolonization, *T. butleri* must have fed on some other prey; Catling and Freedman (1980) suggested leeches. It is also possible that *T. butleri* fed on primary invaders, such as *Plethodon cinereus, Hyla versicolor*, *Pseudacris* spp., and *Lithobates* (=*Rana*) spp. which would have preceded it in colonizing glaciated terrain.

The common garter snake, *Thamnophis sirtalis* (to 137.2 cm TL [Ernst and Ernst, 2003]) has a striped pattern, with lateral stripes on dorsal scale rows 2 and 3; a vertebral stripe is also usually present. In the Great Lakes region, some populations contain a high percentage of melanistic individuals.

The common garter snake is distributed from the Atlantic Coast to the Pacific Coast, and is found further north in Canada than any other snake (Ernst and Ernst, 2003). It has been documented from every state except Arizona; it is uncommon in most of the Southwest, however.

When it comes to diet, adult *Thamnophis sirtalis* are generalists, feeding on amphibians, earthworms, nestling birds, and even carrion (Ernst and Barbour ,1989; Gray, 2002); however, juveniles in some populations may feed exclusively on earthworms (Fitch, 1965; Holman and Harding, 2006). Kirschenbaum et al. (1986) demonstrated that earthworms (*Lumbricus terrestris*) produce a cuticle collagen-like substance, readily detected by the vomeronasal apparatus of *T. sirtalis* that enables the snakes to locate their prey. The range of *T. sirtalis* overlaps in whole or in part with all native and exotic genera of earthworms (Tables 1 and 2). Only exotic earthworms, *Allolobophora caliginosa* (= *Aporrectodea* spp.), *Lumbricus rubellus* and *L. terrestris*, have been recorded in the diet of wild *T. sirtalis* (Uhler et al., 1939, cited in Mitchell [1994]; Hamilton, 1951; Fitch, 1999). In captivity *Lumbricus terrestris* and *L. rubellus* were consumed (pers. obs.). Reports of predation by this snake on earthworms that identify the prey as to species would be noteworthy.

Holman and Harding (2006) noted that in urban areas *T. sirtalis* may be able to survive on an exclusive diet of earthworms. Fitch (1965, 2006) over the course of his studies at the Fitch Natural History Reservation, noted that during drought years when earthworms are less available, the survival of first-year young *T. sirtalis* was negatively affected. Droughts likely affect other vermivorous snakes similarly.

Thamnophis sirtalis is considered a primary invader of formerly glaciated regions (Holman, 1992). Like *T. butleri*, some populations of *T. sirtalis* in glaciated northern regions have presumably shifted their diet from primary invaders such as amphibians during recolonization, to exotic earthworms.

The lined snake, *Tropidoclonion lineatum*, is a small (to 57.2 cm TL [Ernst and Ernst, 2003]) snake that resembles a garter snake in pattern; the body has a brownish dorsal surface with light lateral stripes on dorsal scale rows 2 and 3, and a light vertebral stripe.

Ernst and Ernst (2003) give the range of this species as extending from southeastern South Dakota to the Gulf Coast of Texas, with scattered populations in northern and central Illinois, southeastern Iowa, east-central Missouri, eastern Colorado, and New Mexico.

Earthworms are the primary prey of lined snakes (Force, 1931; Collins and Collins, 2006). The western range limits of *Bimastos* spp. and *Diplocardia* spp. overlap with most of the range of *T. lineatum*; however, other than *Diplocardia* spp. in northeastern New Mexico (Reynolds and Damoff, 2009), native earthworm species have not been documented from the westernmost portion of the range of *T. lineatum* (Figure 4). Lined snakes in Colorado present an interesting area of study for both herpetologists and oligochaetologists. In the eastern half of

Colorado *T. lineatum* is patchily distributed, being documented from Adams, Arapahoe, Baca, Bent, Boulder, Cheyenne, Douglas, Elbert, Jefferson, Lincoln, Otero and Prowers Counties (Hammerson, 1999). Of these counties, only six (Adams, Boulder, Douglas, Ebert, Jefferson, and Lincoln) have been sampled for earthworms; however, with five or fewer records each, these counties are under-surveyed for earthworms (Damoff and Reynolds, 2004). No native earthworms have been documented within the state (Reynolds and Reeves, 2003; Damoff and Reynolds, 2004). However, Damoff and Reynolds (2004) noted that "it is reasonable to expect the presence of native earthworms in Colorado, especially in consideration of the occurrence of native species in those adjacent states in which records of earthworms have been reported." Future surveys by oligochaetologists in Colorado may wish to search for *Diplocardia* in undisturbed habitats in the counties listed above, especially where populations of *T. lineatum* are known. A similar strategy could be used in New Mexico, where records of native earthworms are few. Oligochaetologists working in New Mexico may wish to consult the range map for *T. lineatum* in Degenhardt et al. (1996). Exotic earthworms in the genus *Aporrectodea* occur throughout the range of *T. lineatum*; a small portion of the eastern end of the range overlaps that of *Amynthas* spp. With much of the western range of *T. lineatum* lacking documented occurrences of native earthworms, one must consider the possibility that the lined snake may have fed on other prey, such as sowbugs and soft-bodied insects and insect larvae (Wright and Wright, 1957) prior to the introduction of exotic earthworms, and now feeds on exotic earthworms because they are ubiquitous and an easily obtained food source. It seems more probable, however, that native earthworms (*Diplocardia* spp.) will be found within much of the western range of *T. lineatum*. Such a finding would support considering *T. lineatum* as an obligate vermivore. Like the earth snakes, *T. lineatum* is likely a surface feeder, although it is capable of burrowing (Ernst and Ernst, 2003). During the Pleistocene, *T. lineatum* was present in the Lubbock Lake / Plainview faunas, somewhat south of the species' present-day range in the Texas Panhandle and somewhat west of its current range in the central part of that state (Johnson, 1986; Holman, 2000).

Several other North American snake species (*Storeria occipitomaculata*, *Thamnophis elegans*, *T. marcianus* and *T. radix*) are known to occasionally feed on earthworms; however, earthworms do not constitute as significant a portion of the diet as they do in the species discussed above. Although the current discussion focuses on North American (north of Mexico) forms, vermivorous snakes also occur in other regions, for instance *Adelophis* spp. in western Mexico; *Adelphicos* spp. and *Atractus* spp. in Central America and South America respectively; as well as *Aspidura* spp., *Calamaria* spp., *Haplocercus ceylonensis*, *Pseudotyphlops philippinus*, *Rhabdops bicolor*, *Rhinophis* spp., *Trachischium* spp. and *Uropeltis* spp. in Burma, India, Sri Lanka and surrounding regions (Parker and Grandison, 1977; Mahendra, 1984; Ernst and Zug, 1996; Mattison, 2007).

Conservation and the possible effects of nonnative earthworms on snakes

Many aspects of snake biology are affected by the abundance of their prey; therefore an understanding of predator–prey interactions is critical for management and conservation of snake species (Weatherhead and Madsen, 2009). Despite earthworms being an important component in the natural diet of many birds, mammals, and reptiles (including snakes), virtually no work has been done to examine the trophic relationship(s) between these predators and various earthworm species (Reynolds, 1980). In addition, to my knowledge, no studies testing whether there are differences in nutritional content between native and exotic earthworm species have been done. What effects will exotic earthworms have on snake populations in areas that were once earthworm-free?

Pisani (2009) noted that populations of vermivorous snakes are very susceptible to land use and management practices that affect hibernacula and availability of earthworms. In areas where droughts are common, native earthworms in the genus *Diplocardia* are able to survive soil temperatures that are fatal to exotic earthworms in the family Lumbricidae (James and Hendrix, 2004). What effects will climate change have on vermivorous snakes in these regions if *Diplocardia* spp. are replaced by lumbricid earthworms?

Finding and preserving areas lacking exotic earthworms, but having native earthworms and vermivorous snakes should be a priority. Kalisz and Wood (1995) speculated that native earthworms would not survive over long periods in wildland remnants in fragmented landscapes, especially those less than 30 ha in area. Habitat destruction and fragmentation are detrimental to both snake and native earthworm populations (Hendrix, 1995; Mullin and Seigel, 2009) and both taxa may benefit from a conservation strategy that aims to conserve intact ecosystems of suitable size that support both vermivorous snakes and native earthworms. Unfragmented old growth forest sites south of the glacial boundary have the greatest potential of having earthworm populations consisting solely of native species (Kalisz and Wood, 1995; Kalisz and Powell, 2000); if such sites also have vermivorous snakes, they also have the best potential of documenting snake predation on native earthworms. Disturbance facilitates invasion of forested habitats by exotic earthworms, and while there is no direct evidence that exotic earthworms have negative effects on snakes, there is a growing body of literature showing that negative effects (e.g., reduction of percent organic matter, loss of forest floor mass, changes in microflora and microarthropods, and decreased plant biodiversity) do occur in northern forests that were previously worm-free (Hale et al., 2005; Hale et al., 2006; Eisenhauer et al., 2007). Removal of the forest floor could also negatively affect salamander populations, and the snakes that feed on them (e.g., *Diadophis punctatus* in northern areas). Once established, it is probably not feasible to attempt to eliminate exotic earthworms from an area (James and Hendrix, 2004); therefore preventing the establishment of exotic earthworms would be prudent. Areas containing exotic earthworms, with and without vermivorous snakes, could be used to test whether there are significant differences in the effects of exotic earthworms on ecosystems. For instance, are earthworm invasions slowed, and the negative effects reduced at sites with vermivorous snakes?

Earthworms often have clumped distributions, corresponding to such factors as vegetation, soil texture, or soil organic matter

content (Hendrix and Bohlen, 2002). It would be expected that vermivorous snake species, especially the obligate ones, would have similar distributions; the patchy distribution of *Virginia valeriae* in Kansas observed by Pisani (2009) may partially be explained by such factors. With the introduction of exotic earthworm species into areas formerly devoid of native earthworms, vermivorous snakes may have been given an opportunity to expand their ranges; *T. brachystoma* in Erie County, northwestern Pennsylvania, may be such a species (Gray, 2005, 2008).

It is hoped that this paper will encourage collaboration amongst herpetologists and oligochaetologists. When studying vermivorous snake species, it would benefit the herpetologist to consult any earthworm surveys done within the state in which they are working. By doing so, they may familiarize themselves with the distribution and habitat preferences of earthworm species most likely to be prey of their study subjects. John W. Reynolds has published earthworm surveys, with county-level distribution maps, for most of the continental United States (for available surveys visit: http://www.inhs.uiuc.edu/~mjwetzel/megadrilogica.home.html). There are several areas where earthworm surveys have not been done, and the potential for discovery of new species still exists (Reynolds, 2004). Reynolds and Wetzel (2008) list Kansas, Nebraska, New Mexico, Texas and Wisconsin (all states with at least one species of vermivorous snake) as being under-surveyed for earthworms. Therefore, earthworms identified as prey to snakes in these states have the potential of augmenting our knowledge of the distribution and ecological interactions of earthworms. As noted above in the short-headed garter snake discussion, even in states that have been more extensively surveyed (i.e., New York and Pennsylvania), opportunity still exists to make significant contributions in understanding the distribution of earthworms found in association with vermivorous snakes. In the Great Lakes region, exotic earthworms found in proximity to vermivorous snakes may be of interest to the Great Lakes Worm Watch Project (www.great lakeswormwatch.org). For these reasons I would encourage herpetologists to collect, preserve, and deposit in a museum collection any earthworms found in association with their study subjects. Reynolds and Wetzel (2004) provide information on how to properly collect data and preserve earthworms for future study. I also encourage oligochaetologists to take note of which snake species are found in habitats with earthworms in their studies—not only because they may represent possible predators, but also because such reports may augment our understanding of predator–prey associations, geographic distributions of earthworms and snakes, and habitat preferences of vermivorous snakes. The current paper is essentially an annotated checklist of which snake species I consider most useful in evaluating the points I have raised. Oligochaetologists wishing to make snake identifications should consult Conant and Collins (1998). Herpetologists wishing to identify earthworms should review Reynolds (1977b, 1995) and Hale (2007) for an introduction to terms and characteristics useful in proper identifications. To guarantee positive identification of earthworm species and to initiate collaboration, contacting an oligochaetologist to identify the specimens is encouraged.

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The Distribution of the Burmese Python, *Python bivittatus*, in China

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We here provide a revision of the distribution of the Burmese python, *Python bivittatus*, in China, as reported previously in Barker and Barker (2008). Information provided to us since the publication of that article allows a more detailed depiction of the natural distribution of the Burmese python in China. We discuss the distribution of the Burmese python in each province from which the species has been recorded.

Fujian

The easternmost dot on the map represents the vicinity of Nanping [Yenping]. Pope (1935) reports that the python was killed in the vicinity of Yenping at an elevation of about 1000 feet (330 m). Pope also mentions that there are "several records for this province" but goes on to say that the Nanping record is the only specific locality. The dot at the southern tip of Fujian refers to the Kinmen Archipelago, where pythons are reported to occur on Queymoy Island (Hsiang, 2009).

Jiangxi

Zhong (1993) reported the presence of Burmese pythons in the extreme southern tip of this province on the basis of a sighting and a shed skin.

Guangdong

Pope (1935) mentioned that the Burmese python could be found in Kwantung Province (now Guangdong) along the southern coastal region from Swatow to Yeungkong. He goes on to state that this species "probably occurs over considerable areas in *extreme southern* China" [italics ours]. The easternmost dot on the coast of this province refers to Hong Kong and the adjacent mainland; there the species is well-known, although considered a rare species (Karsen et al., 1986). The dot just to the west refers to Macao (Zhao and Adler, 1993). The locality in north-central Guangdong is based on the report of Xu and Jim (2003) and refers to the Shimentai Nature Reserve situated in Yingde. It is the northernmost record in Guangdong of which we are aware; we placed the northern limit of the range about 50 km north of this record, as indicated by the shaded area on our map, because of similar elevation and habitat.

Hainan

The species is well-known from Hainan Island. Pope (1935) examined several specimens from this locality.

Guangxi

We are unable to find specific locality records of Burmese pythons for this province. It is widely accepted in the literature that pythons are found across the southern half of this province. We have illustrated the range with two northward extensions on the basis of river drainages.

Guizhou

There are three closely grouped localities for Burmese pythons in south-central Guizhou (Zhao et al., 1998). The elevation of the westernmost locality, listed as Wangmo [Wang Mo], is about 600 m. To the east, the elevation of Luodian is about 500 m. The town of Ziyun [Zi Yun] is the northernmost of the three, located at an elevation of 1100 m; we note that nearby to Ziyun, about 2 km southwest, is a deep valley, the bottom of which is 500 m elevation.

Yunnan

Much of Yunnan is a high rocky plateau, the Shan Plateau, dissected with river courses, many of which are tributaries of the main rivers draining the Tibetan Plateau. Most of the ten Burmese python localities listed by Zhao et al. (1998) are associated with various drainages that offer lower elevations and far warmer conditions than up on the plateau.

The easternmost locality is on the Vietnamese border at Hekou, at an elevation of about 150 m on the Yuan Jiang; upon crossing into Vietnam the river is known as the Song Koi (Red River), flowing on to the coast at Hanoi. Further upstream on the Yuan Jiang, northwest of Hekou, is the locality of Yuanjiang [Yuankiang], and the specimen from there was collected at

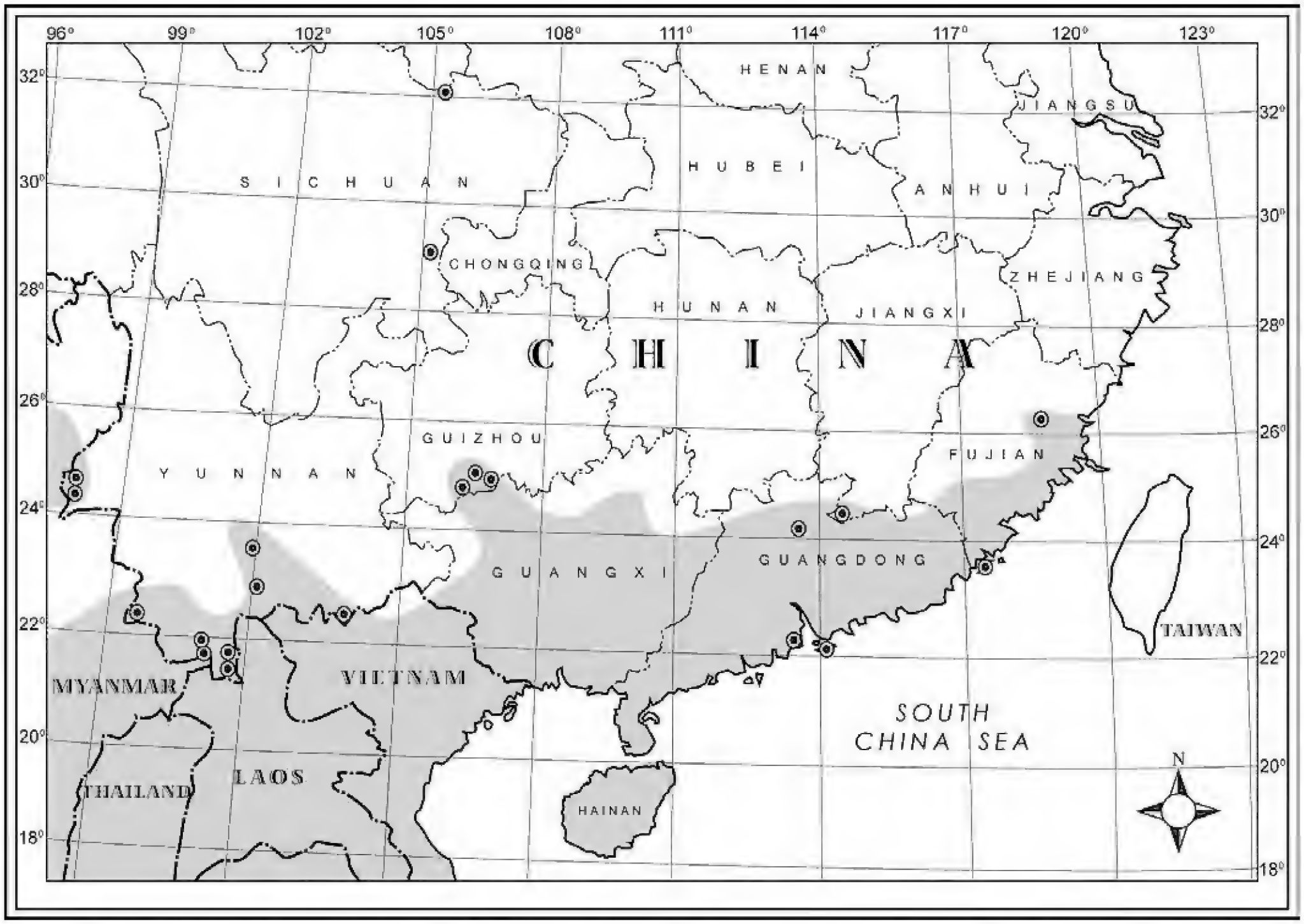

Figure 1. The Distribution of the Burmese python, *Python bivittatus*, in China. The shaded area represents the natural distribution of the Burmese python. The circles with black centers mark published Chinese localities for the species. The range of this species is also indicated in adjacent areas of Vietnam, Laos, Thailand and Myanmar.

about 500 m elevation (first reported by Pope, 1929, 1935).

South of Yuanjiang is the locality of Luchun [also Lüchun or Lachun]. Luchun is located on a ridge between the Yuan Jiang and the Amo Jiang drainages at about 1100 m. There are significantly lower elevations nearby in drainages to the west and east.

The two localities on the Laotian border are both at about 700 m; the more southern locality is Mengla [Meng La] and a few kilometers to the northwest is Mengyuan [Meng Yuan].

There are two localities on the Lancang Jiang [Mekong River] near the Myanmar border. The more northern is Jinghong at an elevation of about 550 m. A few kilometers downriver, south of Jinghong, is Meng Han [Gan Lan Ba]; the elevation of Meng Han is about 500 m.

Further to the northwest is the locality of Menglian [Meng Lian], positioned at about 1000 m elevation on the Nanlei River. The Nanlei flows south into Myanmar, eventually turning to the east and joining the Mekong River.

The two most northwestern localities are along the Myanmar border. Yingjiang is located on the Daying Jiang at an elevation of about 800 m. The more southerly of the two localities is Longchuan, located on the Longchuon Jiang at an elevation of about 900 m. Both of these rivers drain to the west and are tributaries in the upper drainage of the Irrawaddy River in eastern Myanmar. These two localities, therefore, represent an eastern extension of the distribution of the Burmese python population associated with the Irrawaddy drainage in Myanmar; they are situated in that drainage similar to the easternmost locality for Burmese pythons in Myanmar of Myitkyina, located to the northwest of Yingjiang.

Sichuan

The presence of Burmese pythons is problematic and controversial. We do not doubt the veracity of the two reports of Burmese pythons in Sichuan. However, we do not include the two Sichuan localities in the shaded area of our map for the following reasons.

The northernmost record is based on a short report by Liu (1986). Zhao et al. (1998) and Yu et al. (2005) also mention this record, but do not add other information or mention any other specimens in that area. So far as we can determine, this is the only record of a python at this locality. According to the report, a government driver discovered a Burmese python dead in a parking lot of a suburban grocery store near a freeway in the county of Qingchuan, located at the northern border of the

province of Sichuan. The locality is given as N32' 35", E105' 14" at 823 m elevation. The driver skinned the snake and took the gall bladder. It's not clear, but apparently the author of the report saw the skin of the snake. The skin was measured at 307 cm, and scale counts around the body were taken. Liu notes that this record of a Burmese pythons is six degrees of latitude north of the next northernmost Chinese locality known.

The second locality in Sichuan of which we are aware is the report of Zhao (1987). The report states that Zhao went to the Miyi Snake Farm to examine a preserved Burmese python that was collected 27 March 1987 in the prefecture-level city of Neijiang, adjacent to the county of Longchang. This record is listed in Zhao et al. (1998) as "Neijiang." We can find no other information about this specimen or other specimens from this locality. Neijiang is located in the southern third of the Sichuan Basin [also referred to as the Sichuan Pendi]. It is located along the Tuo Jiang, and the elevation of the river in the city is about 300 m. We note that Neijiang was a densely populated area in 1987 and today has nearly 5 million residents.

It occurs to us that expanding the range of the Burmese python in China to include these two localities would be akin to finding a dead eastern indigo snake—a native of Florida north to central Georgia—in Baltimore, and another in New York, and on the basis of that, drawing the distribution of the indigo snake to include the entire eastern seaboard. We consider these two reports as anomalous records, and feel that it is far simpler to assume that they are escaped captives rather than some small natural population hiding in a city of 5 million people.

There is no simple zoogeographic explanation based on either migration or vicariance that would account for the presence of Burmese pythons in the Sichuan Basin. They have either been released by humans, or have existed there since at least the last interglacial period, more than 100,000 years BP; in that case systematic analysis using genetic characters will undoubtedly determine which is the case.

With this explanation and based on the information that has been made available to us, we do not include Sichuan in the range of the Burmese python.

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What You Missed at the April Meeting

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Enthusiasm alone cannot make a good speaker, but it certainly makes a good speaker better. Jeff Lemm is a good speaker and his enthusiasm makes him a really good speaker, but from personal experience, I can say that his presenter persona is little different from his everyday persona. Almost the stereotypical Irishman (except with a California accent), he is a great companion and an avid, maybe fanatic, herper. He can fill long car rides with tales and jokes (some of which are awful), expound on the most scientific of subjects with expertise, and rarely runs out of steam when pursuing his goals. His presentation was much like having a conversation with him, for he knows when to talk and when to listen in a conversation. During his presentation he showed the same sense of timing, often allowing his pictures to fill silences and demonstrating that even in front of a crowd he can deliver a punch line.

Jeff Lemm at the microphone. Photograph by Dick Buchholz.

He's got the famous part of being rich and famous mastered, but unfortunately he's still working on the other half. He works for the Institute for Conservation Research at the San Diego Zoo. He's done research on rock iguanas and monitors and works with many of the endangered animals of California. Since the age of five or six when he caught his first snake, he's been in love with herps, and field herping is still one of his favorite activities. He gets excited over almost every herp find, and I can personally testify to his indefatigability. He's also a self-proclaimed photo freak, and mentioned that he'd taken about six thousand photographs on his African trip in 2006. Which is what his talk was about.

He titled it "Herping the Dark Continent: Exploring Africa's Charismatic Fauna (and the Insects, Birds, and Mammals Too!)," and he took some 500 of those photos, combined them into 220 slides, and created a talk that allowed us to experience Africa the way Jeff experienced it, albeit without the stings, scrapes, smells, illnesses and dangers that he tolerated. With the pictures all labeled and animals named (all herps with scientific names), his slide show obviously took much time and effort to prepare. Accompanied by Jeff's monologue, the end result cannot be adequately described, but I'll try to give you a little taste.

He started with maps. I like maps and I like knowing where things are, so I appreciated the overview of his travels, which lasted three weeks and covered South Africa, Tanzania and Zanzibar.

The entire trip combined several shorter trips with different participants, with the one constant companion being Donald Schultz, a native South African now with his own TV show.

The first stop included some hot-snake handling tips for the group by Mike Perry, a well-known South African venomous snake handler who allowed Jeff to play with a rinkhals cobra (*Hemachatus haemachatus*), which Jeff claims is not a spitting cobra but a drooling cobra which "chucks loogies" at you after working up a mouthful. One still needs eye protection even though rinkhals don't have the spitting-fang apparatus and Jeff mentioned that these cobras play dead and then leap into action when approached. I'll keep my distance, thank you.

Jeff labeled a phenomenon that I've noticed frequently on CHS field trip. Not being a photographer (because I take horrible pictures), I'm amused by (and jealous of) the "snake paparazzi" as they cluster around the latest find. I wouldn't have thought to call it that, but Jeff had many photos of these people in action, including, of course, himself. And, like him, our paparazzi often produce stunning photos.

His photography skills were definitely not limited to herps. He took gorgeous landscapes and informative local color pictures, such as the photos of the Johannesburg neighborhood featuring a brand new sub division across the road from a truly awful slum. South Africa is a land of contradictions. He had shots of elegant lodges and basic tent camping. And enough photos of the dangerous African beasts that we were constantly reminded that often a traveler takes his life in hand by leaving the protection of a car.

At Lindani Preserve he had photos of his interaction with an African bullfrog (*Pyxicephalus adspersus*), which he claimed was more terrifying than handling crocodiles, and a shot of a huge Jerusalem cricket a fellow traveler had captured. Jeff, not being a bug guy, promptly fed it to the huge African bullfrog,

The terrifying and vicious African bullfrog (*Pyxicephalus adspersus*).

Banded rubber frog (*Phrynomantis bifasciatus*).

Giant legless skink (*Acontias plumbeus*).

A somewhat reluctant photographic subject.

Eastern tiger snake (*Telescopus s. semiannulatus*).

Spitting cobra (*Naja nigricollis*).

Sand lizard (*Nucras* sp.).

thereby making both man and frog happy. When these frogs get hit by cars it looks as if a watermelon had been shattered on the road. Heart-breaking shots of road-killed wildcats, snakes, and hyenas continually brought us back to the reality of Africa as not a total paradise.

With a sharply executed back bend Jeff demonstrated his "Matrix move" that allowed him to escape the strike of a 14-foot Natal python (*Python natalensis*) his group was called to relocate. The audience roared as Jeff described how that maneuver caused him to fall into an aardvark burrow, trapping him and leaving him a pinned target of the very disgruntled and aggressive python until Donald saved him with a mid-air head grab. As he finally extracted himself from his prone position, he stood and discovered that he was now under attack by wasps that had nested in the burrow. To the amusement of everyone in the group except Jeff, he flailed around trying to discourage the wasps. Fortunately, they were able to release the python in a nearby reserve and no one else got stung. Jeff had photos of the snake, but unfortunately, no photos of his acrobatics. I suppose he was too busy to take any.

More animal photos were forthcoming, including elephants, rhinos, and a Mozambique spitting cobra (*Naja mossambicus*). He included a slide of three of the group in a canoe attempting to use snake tongs as paddles. The slide was labeled, "Note: snake tongs suck as paddles." He had photos of zoos that made us cringe, including one of the sorriest ostriches he'd ever seen, and keepers that had collections of venomous snakes that rival huge and well-known zoos. A close up of a baboon spider in defensive mode filled the screen. They're as big as tarantulas, but way nastier and much faster.

He traveled to Kruger National Park, satisfying a lifelong dream, and found the hit list for most visitors, the "'big five"' that includes the elephant, rhino, leopard, Cape buffalo, and lion in four hours. Pictures of birds and antelopes, Nile crocodiles (*Crocodylus niloticus*) and blue-headed agamas (*Acanthocercus atricollis*) kept us focused on the screen. "Think of a bearded dragon with a blue head that likes trees," was how Jeff described the agamas.

Donald Schultz pulled the rental van into a group of baboons, putting Jeff right beside a large male . . . and then rolled down Jeff's window. Baboons are notorious for chewing on people, Jeff doesn't get along with monkeys anyway, and he was getting rather anxious as the baboon began to threaten. As he pleaded for Donald to roll up the window, Donald leaned over and loudly huffed "ooh!" That's the incident that led to Jeff playing squirt gun with a spitting cobra. No, I'm not going to tell you everything and you certainly shouldn't be doing that at home!

We remain riveted by close-up shots of a leopard and artfully arranged photos of herpers snoring in the back seat of cars. Yellow-billed kites and vervet monkeys flash by our eyes. Posted signs warning, "Trespassers will get bitten by snakes" and "Lions. Stay in vehicle" abounded. And always, among the habitat shots, the people shots, and the paparazzi shots, splendid photos of stiletto snakes (*Atractaspis bibroni*), reed frogs (*Hyperolius marmoratus taeniatus*), boomslangs (*Dispholidus typus*), eastern tiger snakes (*Telescopus s. semiannulatus*), flap-necked chameleons (*Chamaeleo dilepis*), and Cape rough-scaled lizards (*Ichnotropis capensis*). Five hundred pictures and over two hundred slides presented in almost exactly one hour by Jeff's easy going delivery that never made it seem as though we were rushing through them.

One of the "big five" on most tourists' lists when visiting Kruger.

From Kruger to a military special forces survival training centre where Jeff unknowingly consumed dried puff adder ("Not cool man, I don't eat herps. That's bad juju."), to a friend of Donald's private collection containing venomous snakes he had never heard of, to the disgusting facilities of one of the more notorious animal exporters in Africa where Jeff nevertheless photographed some rare snakes that one's not likely to ever see, to Tanzanian villages that specialize in supplying the export trade. Don't buy wild caught herps! We saw Jeff four-wheeling and scuba diving, Africans smiling at Jeff and running from Jeff, Hluhluwe Imfolozi Park and Ngorongoro Crater, sungazers (*Cordylus giganteus*) and red hartebeests, cycads and sausage trees, eagles and kingfishers. And at the end, unusual for our audience, almost no questions, I think not because we didn't have any, but maybe because we were still trying to absorb our trip through Africa. Heck, I'm still trying to absorb it.

The day after the meeting a group of us had the pleasure of escorting Jeff into the wilds of southern Illinois, where I was lucky enough to spend more time with Jeff than he probably preferred. While we couldn't match Africa, we managed to find a few challenging experiences for him and had the pleasure of getting to know him better. After watching Jeff in action I fully understand why he could accomplish what he did in only three weeks in Africa and why I'm sure that he will never lack for herping companions. His easy-going nature and affable personality make him a totally enjoyable herping partner. And I selfishly admit that I'm a little happy that he didn't find the big three of his Illinois hit list on this trip, because I think that means I have the chance to go herping with him again.

How do we find these speakers?

Herpetology 2010

In this column the editorial staff presents short abstracts of herpetological articles we have found of interest. This is not an attempt to summarize all of the research papers being published; it is an attempt to increase the reader's awareness of what herpetologists have been doing and publishing. The editor assumes full responsibility for any errors or misleading statements.

GRASSLAND SNAKE ASSEMBLAGES

W. E. Meshaka, Jr., et al. [2009, The Herpetological Bulletin (110):8-19] during 2001–2009 surveyed snake assemblages from 15 grasslands in central and western Pennsylvania and northeastern Ohio, and found that in smaller sites (4.6 ha) the common garter snake (*Thamnophis sirtalis*) was nearly always the dominant snake out of as many as eight species found under cover boards, and generally followed by smaller, fossorial species that were considerably less abundant. At the single large site (101 ha), large individuals (> 105 cm SVL) of the midland rat snake (*Scotophis spiloides*) and the eastern racer (*Coluber constrictor*) greatly outnumbered other species and no common garter snakes were captured. Although not confirmed, the small size and isolated nature of the smaller grassland sites may have been the reason for the absence of the eastern racer. However, in domino effect, the absence of this large-bodied ophiophage may have allowed the common garter snake to dominate, which in turn may have been a superior competitor for earthworms and also a possible predator of its competitors. Habitat structure of these sites appeared to be responsible for the status of some of the species as well as non-competitive, larger species at these sites. Thus, whereas conservation of the eastern racer is tied, in part, to large parcels of early successional grasslands, somewhat predictable responses by northeastern grassland snakes to successional changes within the grassland must also be taken into account when formulating conservation plans for disappearing habitat in the northeastern United States.

JUMPING AT SHADOWS

W. E. Cooper [2009, Behaviour 146(9):1217-1234] notes that because predators attacking from above may cast shadows on prey, diverse prey have evolved behavioral responses (fleeing, freezing, descending in water) to shadowing. The author studied escape responses to shadow in three lizard species by passing a hand overhead, casting a shadow on them or not. Theory predicts immediate fleeing when a predator is detected closer than the optimal flight initiation distance (predator-prey distance when escape begins). Predictions that *Sceloporus virgatus*, *S. jarrovii* and *Urosaurus ornatus* are more likely to flee and to either flee or adopt alert postures when covered by shadow were verified. Probability of fleeing or alerting did not differ among age/sex groups in *S. virgatus*. For probability of fleeing, shadow and age/sex group effects interacted, juveniles seeming to be slightly less likely to flee from shadow. *Sceloporus virgatus* covered by shadow fled more frequently on horizontal than vertical surfaces, when fully exposed than beneath overhanging objects, and when shadow encroached rapidly than slowly. These findings are consistent with the hypothesis that probability of fleeing is greater when shadow is more likely to indicate attack. Responses to sudden covering by shadow conform to predictions based of escape theory based on predation risk.

HELLBENDERS IN THE ALLEGHENY RIVER DRAINAGE

R. L. Foster et al. [2009, J. Herpetology 43(4):579-588] note that studies that document changes in long-lived species are valuable in determining how demographic and environmental changes are affecting populations. This study documents apparent declines in eastern hellbender (*Cryptobranchus alleganiensis*) populations over the last 20 years in the Allegheny River drainage of New York State. This study compared current mark–recapture data to similar data collected in the 1980s at eight sites using a comparable method of capture (rock turning). In addition, several other methods of capture were employed, including trapping, bank searching, and night lighting. Despite these extra efforts, the number of hellbenders captured was less than the number captured historically. Hellbenders were extirpated from a single site and the ecological density (number of individuals per 10 m^2 of habitable area) decreased in several other sites relative to the 1980s. Current and historical populations contained more mature adults than juveniles, but more hellbenders <20 cm total length were found at five sites compared to the 1980s study. The sex ratio changed from predominantly female in the 1980s to predominantly male currently. Eggs in nests were found in both studies, although little is known about egg or larval survival and overall recruitment. Although demographic issues such as reproduction and recruitment may be contributing to hellbender declines in the Allegheny drainage, these do not appear to have changed drastically from the 1980s. Other possible causes of decline include factors such as land use changes, introduced species, or some other environmental issue.

MINIATURIZATION IN DUSKY SALAMANDERS

R. C. Bruce [2009, Copeia 2009(4):714-723] investigated the contributions of several life-history traits to small body size in the two smallest species of the genus *Desmognathus*, *D. aeneus* and *D. wrighti*. The research was conducted in the southern Nantahala Mountains of western North Carolina, where the two species co-occur and are similar in body size and life history. *Desmognathus ocoee*, the next-smallest species in the local *Desmognathus* assemblage of six species, served as a reference species. All three species have similar juvenile growth rates. *Desmognathus aeneus* and *D. wrighti* have smaller propagule sizes (i.e., egg and hatching sizes) and higher developmental rates to sexual maturation than *D. ocoee*. These two factors, especially the latter, appear to explain much of the difference in adult size between *D. ocoee* and both *D. aeneus* and *D. wrighti*. Thus, miniaturization in *D. aeneus* and *D. wrighti* may be mainly a product of acceleration in developmental rate. The author suggests that body size itself, rather than other, correlated life-history traits, has been the target of selection in these two species, in response to ecological opportunities for small salamanders in the mesic forests of the southern Appalachian Mountains.

HERBICIDES AND SALAMANDERS

R. Brodman et al. [2010, J. Herpetology 44(1):69-82] report that pesticides can be important conservation tools, but they could have unintended impacts on amphibians. The commercial glyphosate-based herbicide Accord is approved for use in wetlands and ponds because it is designed to be safer to aquatic wildlife than other herbicide formulations (e.g., Roundup or Atrazine); however, field experiments are needed to determine whether there are direct, indirect, or sublethal effects on amphibians or effects on wetland community structure. The authors conducted a replicated field experiment in constructed ponds to test for both the effects of Accord and predator (tiger salamanders, *Ambystoma tigrinum*) density on amphibians and aquatic invertebrates. Herbicide treatment had significant density-dependent effects on tiger salamander growth, development, and survival. The survival of anurans and aquatic invertebrates was also affected by herbicide treatment and predator density. At certain tiger salamander densities, the community structure was altered such that some species became more common with herbicide treatment, whereas others became less common. Behavior assays of salamander larvae suggest that herbicide treatment alters predator-prey relationships in the experimental pond communities. These results suggest that competition and predation may mediate indirect effects of this herbicide on the aquatic fauna. The authors conclude that exposure to Accord poses less of a risk to the ecology of amphibians than do other formulations of glyphosate-based herbicides.

PATTERNS OF REPTILE ROAD-KILLS

R. Meek [2009, The Herpetological Journal 19(3):135-142] recorded road mortalities of two lizard and four snake species in the Vendée region of western France over a period of four years. Road-kills were more frequent in the foraging snakes *Hierophis* (= *Coluber*) *viridiflavus* and *Natrix natrix* as well as the lizard *Lacerta bilineata*, and lower in the small lizard *Podarcis muralis* and the sedentary snakes *Vipera aspis* and *Natrix maura*. Road-kills were found throughout the active year, with differences in size class and monthly frequencies in *H. viridiflavus*, *N. natrix* and *L. bilineata* commencing in June. Pearson rank correlation coefficients revealed a significant positive association between monthly road-kill and monthly live counts of *H. viridiflavus* and *N. natrix*, suggesting regular road crossings in these species. Road traffic volume was related to the number of road deaths using regression analysis of the log-transformed data. This gave an allometric equation with an exponent of 0.75, which was not significantly different from 1, the exponent required if road-kills increase in direct proportion to increasing road traffic volume. The highest traffic volume route showed lower than expected mortalities, but fewer numbers of species living in the vicinity. Models of road-kill vulnerability in *H. viridiflavus* and *N. natrix*, derived from the integration of size frequencies of road-kill and live distributions, predict high vulnerability in small and large individuals. In lizards, particularly *L. bilineata*, road basking is probably the main factor determining mortality, in addition to species velocities, traffic volumes, road widths, abundance at the sides of roads, and behavior and activity patterns.

SURVIVAL OF NEONATE ROCK IGUANAS

C. R. Knapp et al. [2010, Copeia 2010(1):62-70] note that the relationship between dispersal and predator–prey interactions in heterogeneous landscapes is an underappreciated factor influencing species persistence. This relationship, however, is critical for understanding population dynamics and for implementing management strategies for species. The authors investigated the influence of habitat heterogeneity and dispersal patterns on neonate survival for the iguana *Cyclura cychlura cychlura* inhabiting Andros Island in the Bahamas. Contrary to the initial hypothesis, there was a clear survival advantage for neonates that spent more time in open mangrove habitat than relatively more closed-canopy habitats, most likely because of fewer primary predators in mangroves relative to other habitats. Snake predation was the most significant cause of mortality for neonates dispersing away from nest sites and was highest during the first week after release. The probability of survival to 28 days ranged from 16.7 to 28.4%. Most neonates displayed rapid, nearly linear movements away from nests for a minimum of 14 to 21 days. Mean straight-line distance away from nest sites for surviving neonates was 601 m. There was a significant positive relationship between mean daily movement rates away from nests and days survived. The authors suspect that the initial and rapid movements away from nests reduce relative predation by dispersing neonates from a zone where predators learn to exploit them. These results have implications for translocation programs targeting endangered insular iguanas throughout the Neotropics because historically only the presence of non-native mammalian predators was used as a metric to evaluate potential translocation sites.

PREY DISCRIMINATION IN TEXAS HORNED LIZARDS

W. E. Cooper, Jr., and W. C. Sherbrooke [2009, J. Herpetology 43(4):688-692] tested tongue-flicking responses to food chemicals and control stimuli in the Texas horned lizard (*Phrynosoma cornutum*) by presenting chemical stimuli on cotton swabs. No evidence of discrimination between prey chemicals (from the ant *Pogonomyrmex rugosus*), plant chemicals (romaine lettuce), cologne, and distilled water via the lingual-vomeronasal system was detected despite extremely high statistical power. The authors conclude that *P. cornutum* does not use tongue flicking to sample chemicals to permit detection and identification of food. Horned lizards forage by moving between ant colonies, capturing numerous ants at each colony by lingual prehension. Because ants are abundant above ground and mobile, visual search may suffice. Despite the absence of evidence for prey chemical discrimination, the lizards tongue flicked up to 15 times in a 60-sec trial. Because horned lizards do not usually enter crevices likely to contain predators and because they rely on crypsis to avoid detection, they are presumably less likely than lizards such as skinks, lacertids, and geckos to use vomerolfaction to detect predators' chemicals. However, horned lizards tongue flick each other during courtship. Therefore, the primary adaptive use of tongue flicking may be for pheromonal communication.

SEXUAL SHAPE DIMORPHISM IN TUATARA

A. Herrel et al. [2009, Copeia 2009(4):727-731] note that the tuatara, *Sphenodon punctatus*, exhibits a male-biased sexual size dimorphism, often attributed to the territorial behavior of males. Data from this study, based on preserved specimens from museum collections, also show a previously undocumented dimorphism in head and limb shape in *Sphenodon*, with males having bigger heads and longer limbs for a given body size than females. A review of the existing literature on the ecology and behavior of these animals suggests that this may provide males with a greater sprint speed capacity relevant to territory defense. Differences in head shape, however, may be related to ecological niche differentiation as males have been suggested to eat larger prey than females, but this remains to be tested. An additional role for sexual selection in driving the divergence in head shape between males and females is likely but cannot be confirmed at present.

ALLIGATOR SNAPPER HABITAT IN ARKANSAS

C. A. F. Howey and S. A. Dinkelacker [2009, J. Herpetology 43(4):589-596] note that habitat selection in adult alligator snapping turtles (*Macrochelys temminckii*) is known for only a few populations. Given that habitat availability can vary in different geographical locations, the authors used radiotelemetry to study habitat selection in a riverine habitat in central Arkansas by attaching radio transmitters to 14 female and four male alligator snapping turtles. They tested the hypothesis that males and females select different habitats throughout the year because of differences in reproductive cycles and higher thermoregulatory requirements for females prior to nesting. Results indicated that males and females selected similar habitats with similar thermal properties, but both sexes selected submerged structure. The tendency for alligator snapping turtles to select sites with structure may be caused by higher prey densities in these areas, protection from predators, or as an aid in surfacing to breathe rather than for thermoregulatory purposes.

HEAD-STARTING WESTERN POND TURTLES

W. M. Vander Haegen et al. [2009, J. Wildlife Management 73(8):1402-1406] note that the western pond turtle (*Actinemys marmorata*) is a species of conservation concern over much of its range and is listed as endangered in Washington State. From 2000 to 2004, the authors used radiotelemetry to document survival of head-started western pond turtles (n = 68) released into Pierce National Wildlife Refuge in southwestern Washington. Survival estimates for first year and older turtles ranged from 86% to 97% and overlapping confidence intervals indicated no detectible differences among age classes or among years. Subadult turtles released at 90 mm carapace length apparently avoided capture by most aquatic predators, indicating that terrestrial predators should be the focus of research and management where predation on larger age classes is a concern. High annual survival combined with documented nesting by 7-year-old female head-started turtles in Washington suggest that recruitment of adults is being achieved; however, head-starting is only an interim solution and strategies for effective removal of aquatic predators must be developed and implemented where natural recruitment is inadequate to maintain populations.

GENE FLOW AMONG TIMBER RATTLESNAKES

C. D. Anderson [2010, Copeia 2010(1):54-61] note that radiotelemetry and genetic markers have enabled herpetologists to test the hypothesis that gene flow is restricted among snake dens (a.k.a. "hibernacula"). In this study, observations of movement and mating were compared to indirect inferences of gene flow based on genetic data (microsatellite DNA loci) for six neighboring hibernacula of the timber rattlesnake (*Crotalus horridus*) in western St. Louis County, Missouri. Behavioral results were consistent with previous findings for this species, with most individuals exhibiting high fidelity to hibernacula, and males exhibiting larger activity areas than females. Behavioral results also supported several long-standing assumptions: males tended to mate at longer distances from hibernacula than females and random pairing between males and females from different hibernacula could not be rejected. Some gravid females moved considerable distances between locations, but most returned to an area near their own hibernaculum to give birth, and birth distances tended to be shorter than the nearest-neighbor distance between hibernacula. Genetic results indicated that the observed number of heterozygotes did not deviate from Hardy-Weinberg expectations at the level of total sample population, but that a significant heterozygote excess was found within hibernacula. A small but significant proportion of the genetic variance in the total population was due to differences among hibernacula; however, Bayesian clustering algorithms could not sort individuals (or groups of hibernacula) into discrete demes. Results suggest that patterns of genetic differentiation observed among hibernacula of the timber rattlesnake are better explained by behavioral and demographic factors resulting in natal philopatry, sex-biased dispersal, and/or a limited number of breeding adults, than by the balance of gene flow and drift, per se.

ANGULATE TORTOISE DIET AND ACTIVITY

Q. I. Joshua et al. [2010, J. Herpetology 44(1):124-134] used focal observations to study the diet of angulate tortoises (*Chersina angulata*) over four seasons at two distinct sites in the southwestern Cape Region of South Africa: the West Coast National Park (WCNP), and Dassen Island (DI). Seasonal fluctuations in temperature, rainfall, and food plant availability influenced the activity pattern and feeding activity of angulate tortoises. Tortoises were more active during the wet season, winter and spring, than during the dry season, summer and autumn. Diet differed between sites and among seasons. WCNP tortoises had a diverse diet of grasses, shrubs, herbs, and succulents, whereas DI tortoises ate mostly herbaceous plants. DI tortoises had few dietary choices available compared to choices available to WCNP tortoises. At both sites, herbs and seedlings were important diet components during the wet season. The dry season diet consisted largely of dry plant material. Angulate tortoises on DI supplemented their intake of dry plant material with rabbit feces, which comprised more than 27% of the diet in summer and autumn. The opportunistic feeding behavior of angulate tortoises helps explain their distribution among a wide variety of habitats. Their persistence in disturbed areas is probably determined by the abundance of easily digestible, herbaceous plants during the wet season and the tortoises' low activity and low metabolic demands during unfavorable periods.

Unofficial Minutes of the CHS Board Meeting, April 16, 2010

The meeting was called to order at 7:42 P.M. at the Schaumburg Public Library. All board members were present.

Officers' Reports

Recording Secretary: Cindy Rampacek read the minutes and corrections were made. The minutes were accepted.

Treasurer: Andy Malawy presented the March financial report. Andy also shared the preliminary numbers for ReptileFest.

Membership Secretary: Mike Dloogatch reported a large number of new memberships from ReptileFest. Mike also shared the un-renewed memberships..

Sergeant-at-arms: Dick Buchholz reported that attendance at the March general meeting was 66.

Committee Reports

Shows (Jenny Vollman):
- Park Voyagers Family Day, April 17
- Cosley Zoo, June 19.

Old Business

ReptileFest: Rick and Mary Hoppenrath handed out several sheets outlining the feedback from 'Fest attendees. Winners for best exhibits were announced as well. For the judged contest, DNR exotics won in the adult category and Joey Robinson won in the 12 and under category. They received their awards at ReptileFest. For the Exhibitors' Choice award, Anna Sullivan won the 12 and under and Dan Nathan won the 13 and over. Awards will be presented at the April meeting. Attendance was lower than last year, but we did make a profit. One highlight of the event was the improved food.

New Business

John Archer was contacted by a person who said that the CHS had been "kind enough to complete the rescue of a large snapping turtle." The person would like photos of the animal if possible. Bob Bavirsha admitted that he was the one who took in the turtle, but no photos were taken.

Wheeling survey: Jason Hood and Lawrence Huddleston will be surveying a park in Wheeling for native herps.

DNR Exotics would like to donate their cash prize from Reptile Fest back to the CHS. It was decided that the money would be used towards the food purchased for the Christmas party.

A representatve of FAUNA Paraguay has asked if we could donate to them a full set of the CHS *Bulletin*. In return they would scan them in digitally. He did not say how long it would take to get the project completed. Consensus was that this might not be out of the question, but we will look into having it scanned locally rather than paying the high cost of shipping.

John Archer suggested we try a new restaurant after the general meeting. Tore's Italian Beef & Pizza, the food supplier for ReptileFest, would be willing to stay open for our group. As of the April meeting, we will try it.

In lieu of the Round Table, everyone shared ReptileFest thoughts and stories.

The meeting was adjourned at 9:34 P.M.

Respectfully submitted by recording secretary Cindy Rampacek

Advertisements

For sale: rats and mice—pinkies, fuzzies and adults. Quantity discounts. Please send a SASE for pricelist or call Bill Brant, *THE GOURMET RODENT*, 12921 SW 1st Rd, Ste 107-434, Jonesville, FL 32669, 352-472-9189, E-mail: GrmtRodent@aol.com.

For sale: from **The Mouse Factory**, producing superior quality, frozen feeder mice and rats. Our mice and rats are vacuum-packed to greatly extend freezer life by reducing freezer burning and preserving vitamin and nutrient content. We feed our colony a nutrtionally balanced diet of rodent chow, formulated especially for us, and four types of natural whole grains and seeds. For a complete price list please visit our web site, www.themousefactory.com. We accept all major credit cards, PayPal or money orders. Call us **toll-free** (800) 720-0076 or send us an e-mail at info@themousefactory.com. Write us at PO Box 85, Alpine TX 79831.

For sale: **high quality frozen feeders**. Over a decade of production and supply. Seven sizes of mice availabe: small newborn pinks up to jumbo adults. Prices start at $25 per 100. Feeders are separate in the resealable bag, not frozen together. Low shipping rates. Free price list. Kelly Haller, 4236 SE 25th Street, Topeka KS 66605, (913) 234-3358 evenings and weekends.

For sale: Rats—live or frozen. I breed rats for my collection of boas so only top quality lab chow and care will do, I'm now offering surplus animals for sale. Located in far south suburbs of Chicago. Only orders of 20 or more please, no large rats will be available. For current availability and prices, please e-mail Steve at smuys@sbcglobal.net.

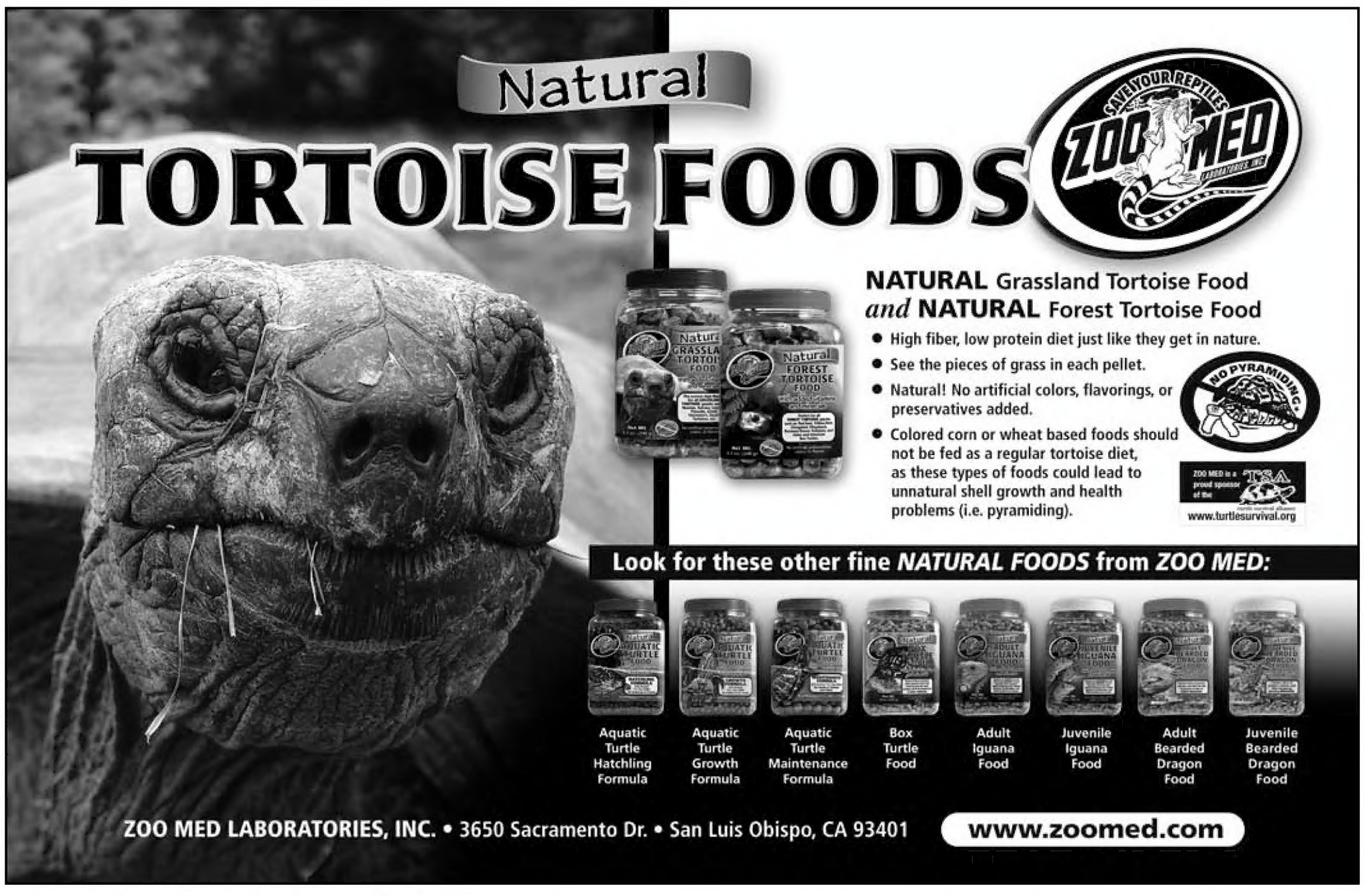
For sale: **Entire reptile collection**. About 120 snakes, turtles and lizards for sale as one complete lot (or will sell all snakes separately). Will pay for you to pick up. Serious inquiries. Henry Cohen, (716) 881-6724 (EST AM) or hencoherp@aol.com

Herp tours: **Biodiversity of the Ecuadorian Amazon: September 19-28, 2010**. Join Biophoria Tours as we travel to the Shiripuno Research Center, one of Ecuador's most pristine and remote preserves in the Amazon. On this trip, our small group will focus on all the wildlife that the Ecuadorian Amazon has to offer. We guarantee this amazing trip will be one you never forget! For more information please email or call: Bryan Suson, (847)-344-9607. www.biophoriatours.com info@biophoriatours.com

Herp tours: The beautiful Amazon! Costa Rica from the Atlantic to the Pacific! Esquinas Rainforest Lodge, the Osa Peninsula, Santa Rosa National Park, and a host of other great places to find herps and relax. Remember, you get what you pay for, so go with the best! GreenTracks, Inc. offers the finest from wildlife tours to adventure travel, led by internationally acclaimed herpers and naturalists. Visit our website <http://www.greentracks.com> or call (800) 892-1035, E-mail: info@greentracks.com

Shed snake skins needed: I am working on an illustrated key to shed snake skins. Shed skins from the following species are desperately needed: *Arizona elegans* (eastern glossy snake); *Charina bottae* (northern rubber boa); *Contia tenuis* (sharptail snake); *Crotalus viridis* (Prairie rattlesnake); *Heterodon nasicus* (western hognose snake); *Hypsiglena chlorophaea* (= *torquata*) (desert night snake); *Rhinocheilus lecontei* (longnose snake); *Sonora semiannulata* (ground snake); *Thamnophis elegans* (western terrestrial garter snake); *T. marcianus* (checkered garter snake); *T. ordinoides* (Northwestern garter snake); *Tropidoclonion lineatum* (lined snake). If you would like to provide shed skins from any of the species listed, please contact me by email: brachystoma@hotmail.com. Or snail mail: Brian S. Gray, PO Box 3515, Erie, PA 16508-0515. All contributors will be acknowledged in any publications that result.

Line ads in this publication are run free for CHS members—$2 per line for nonmembers. Any ad may be refused at the discretion of the Editor. Submit ads to: Michael Dloogatch, 6048 N. Lawndale Avenue, Chicago IL 60659, (773) 588-0728 evening telephone, (312) 782-2868 fax, E-mail: MADadder0@aol.com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UPCOMING MEETINGS

The next meeting of the Chicago Herpetological Society will be held at 7:30 P.M., Wednesday, May 26, at the Peggy Notebaert Nature Museum, Cannon Drive and Fullerton Parkway, in Chicago. **Dr. Dante Fenolio**, Amphibian Conservation Biologist with the Atlanta Botanical Garden, will speak about "Life in the Dark"—cave salamanders, etc.

The June 30 meeting will be our popular and always well-attended annual **Show & Tell** meeting. Bring an animal that you find interesting for one reason or another and be prepared to give a short (under five minutes) presentation to the group. Don't be shy. Neither age (yours) nor commonness (the animal's) should be a limitation.

The regular monthly meetings of the Chicago Herpetological Society take place at Chicago's newest museum—the **Peggy Notebaert Nature Museum**. This beautiful building is at Fullerton Parkway and Cannon Drive, directly across Fullerton from the Lincoln Park Zoo. Meetings are held the last Wednesday of each month, from 7:30 P.M. through 9:30 P.M. Parking is free on Cannon Drive. A plethora of CTA buses stop nearby.

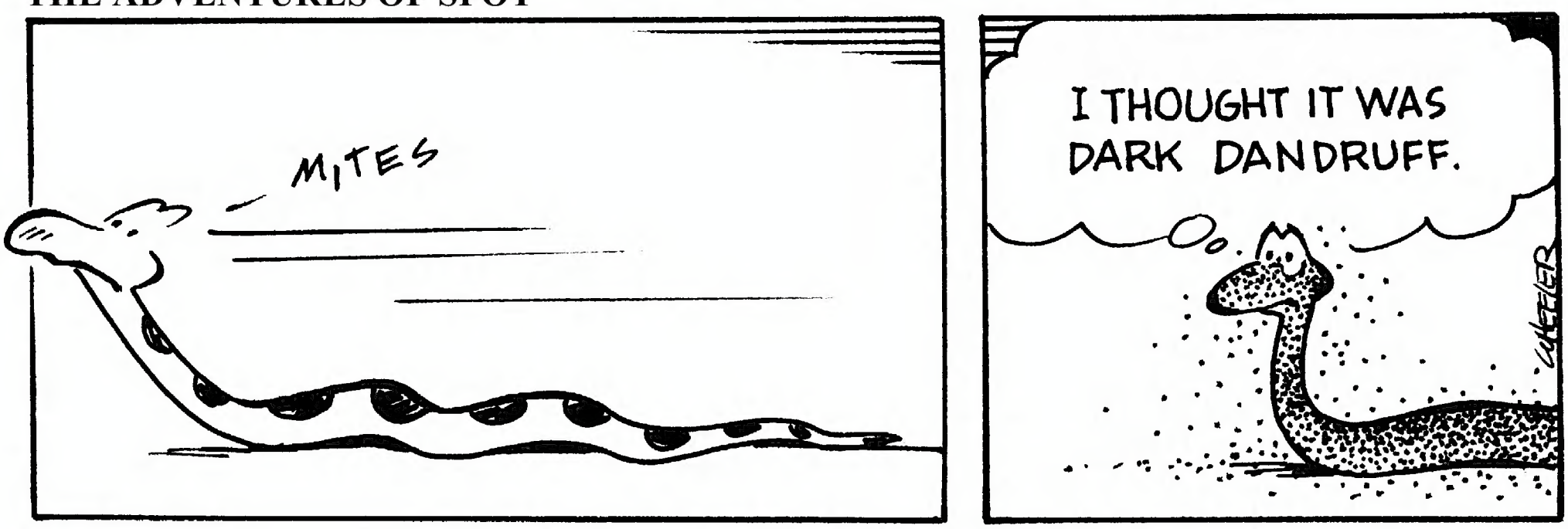
Board of Directors Meeting

Are you interested in how the decisions are made that determine how the Chicago Herpetological Society runs? And would you like to have input into those decisions? If so, mark your calendar for the next board meeting, to be held at 7:30 P.M., June 18, in the adult meeting room on the second floor of the Schaumburg Township District Library, 130 S. Roselle Road, Schaumburg.

The Chicago Turtle Club

The monthly meetings of the Chicago Turtle Club are informal; questions, children and animals are welcome. Meetings normally take place at the North Park Village Nature Center, 5801 N. Pulaski, in Chicago. Parking is free. For more info visit the CTC website: http://chicagoturtle.org/.

THE ADVENTURES OF SPOT



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